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PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 6 (Revised).

Formerly Bulletin No. 9.

HOLLOW BRICK ARCH

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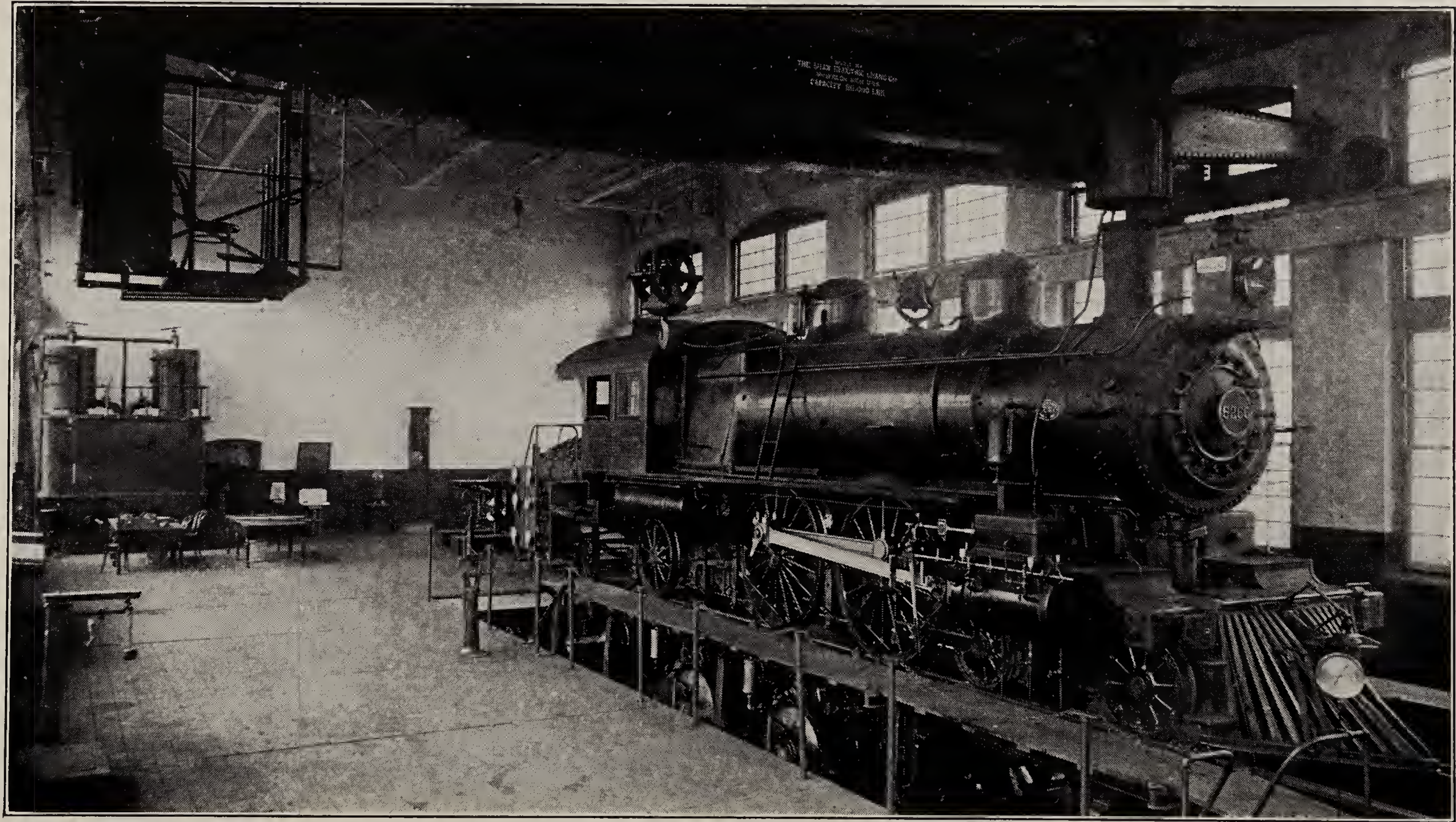


LOCOMOTIVE 5266, CLASS E2a, IN POSITION FOR TEST.
Locomotive Testing Plant, Pennsylvania Railroad Company, Altoona, Pa.

LOCOMOTIVE TESTING PLANT.

TESTS WITH HOLLOW BRICK ARCH.

(Conclusions and recommendations on pages 6 and 7.)

INTRODUCTION.

1. For the improvement of combustion in locomotive fireboxes many devices have been suggested, one supposed to have merit being the hollow arch. This arch, in addition to maintaining a uniform furnace temperature, by its mass of heated bricks, also admits air above the fire to unite with the combustible gases. Combustion of these gases is, in many cases, but partly completed on account of the limited supply of air that is drawn through the grates, and it has been thought that, if additional air, passing through a hollow arch and becoming heated, could be mixed with the gases, combustion would be completed with beneficial results in economy of coal and emission of smoke. These expectations in regard to air admission were not realized, however, and the hollow arch did not show any marked advantages over an arch without air admission, but the advantages of the latter are brought out.

Description of the Arch.

2. A detail of the arch and the method of its application are shown in Fig. 6. As will be seen, the arch was formed of fire-clay segments $8\frac{3}{8}$ inches wide, made in two pieces and fitted together at the center of the span. These segments were hollow, having air passages through them. The arch was supported by angle irons held by studs in the firebox sides. Air was admitted to the air passages by holes drilled in the dead grate castings at the front of the firebox.

3. The combined area of the six air passages through the arch was about 60 square inches, or only 0.75 per cent. of the grate area. The total area of the openings in the dead grate below was 140 square inches.

Method of Making the Tests.

4. An arch of the hollow brick form arranged for air admission was applied to class "E2a" locomotive No. 5266, and with modifications, tried out in a number of tests, other tests being made on the same locomotive without an arch, all on the Locomotive Testing Plant, for the purpose of determining to what extent the amount of smoke could be reduced by such means, and whether and how much the evaporative efficiency of the boiler could be improved.

5. All of the tests with arch, with one exception, No. 900.16, were made at a speed of about 38 miles per hour, or nearly 160 revolutions per minute, with a cut-off of 25 per cent. and fully open throttle.

Modifications of Arch:

6. The first arch tried was the short form as shown in Fig. 4. The arch was next extended, as shown in Fig. 5, and in order to strengthen the end support for the arch it was necessary to cover 15 tubes.

7. The arch in the second form cracked between the air passages, and just after the test was completed the lower part of the arch separated completely and fell down. It was then rebuilt with new bricks in the form shown in Fig. 6, where it will be seen that the front end of the arch is brought much lower down and is well supported without covering any tubes. The supporting angles were increased in size to 2½ by 2½ inches, as lighter angles used in the first arches were found to sag between fastenings.

8. With this large arch, in two tests, the back end of the grate was blocked off so that the total grate area was reduced from the normal area of 55.5 to 39.5 sq. ft., or a reduction of about 29 per cent.

9. In three tests the air inlets to the arch were closed with fire-clay so that the arch would act as a simple arch without air admission.

10. When the air entered the firebox through the arch there was no means of determining what proportion of the air leaked through the joints between the arch segments. It was not possible to make these perfectly air tight.

11. One test, No. 900.16 with arch, and in which test the minimum amount of smoke was produced, was made at a lower speed and earlier cut-off than the others, and air was admitted to the firebox through the firedoor, which was kept on the first notch of the latch all of the time except when firing coal. No air was admitted through the arch in this case, while in the other tests the firedoor was kept closed when not firing coal.

12. The coal used was, in four tests, "Run of Mine Penn Gas," in seven tests, "Screened Penn Gas," and in one test "Scalp Level," see tables 1 and 2.

13. Penn Gas coal has about 36 per cent. volatile combustible material, and while a good coal it is smoky on account of the large amount of volatile matter. It is a coal which should show improved performance with an arch, the object of which is to maintain a high furnace temperature and thus consume all of the volatile gases as they are given off from a new charge of fuel.

14. Scalp Level coal is, on the other hand, a very low volatile coal for a bituminous coal, having as little as 16 per cent. of volatile combustible matter, or less than half that of the Penn Gas coal.

Results of Tests.

15. The results are given on table 2. Tests 900.2 and 952, made without any arch, are shown for comparison. Also in table 1 are given two additional tests, Nos. 900.1 and 951, without arch, for comparison of smoke readings.

16. The test results are plotted in Figs. 7, 8, 9 and 10. On these diagrams no curves are drawn through the points representing the brick arch tests, but the number of the test is given in each case opposite the points plotted. Other points are shown and curves drawn to show results obtained with the locomotive without any arch in the firebox, but fired with the same kind of coal.

Temperatures;

17. The arch covered the opening in the side of the firebox and prevented the use of a firebox pyrometer, except for two tests, and in these the temperature was about 15 per cent. higher with the arch than without. This is shown in Fig. 7.

Evaporation:

18. All of the tests with the arch and high volatile coals show results in evaporation per pound of coal above those obtained without the arch. There appears to be an improvement in evaporation with each increase in the length of the arch, and the best evaporation obtained was with the long arch without air admission through the arch.

19. Test 900.17 made with Scalp Level coal, with the arch and without air admission, gave an equivalent evaporation per pound of coal of 7.79 pounds, while a test of this coal, under like conditions but without an arch, shows an evaporation of 7.64 pounds, or practically the same result.

20. Scalp Level coal, however, is almost a semi-anthracite, and gives results fully equal to the screened Penn Gas coal when not burned too rapidly, but its evaporation falls off sharply when forced, on account of unburned coal lost through the stack.

21. From these tests, at rather a low rate of combustion for Scalp Level or a low volatile coal, it would appear that the steaming of this coal cannot be improved by the use of an arch.

Smoke:

22. Observations of the effect of the arch upon the smoke were made according to the Ringelmann method. The average smoke readings are given in the following, table 1:

TABLE 1, Smoke with Arch.

Test No.	SPEED.	CUT-OFF.	Throttle.	SMOKE.	ARCH.			COAL.	GRATE.
	Miles per hour.	Per cent.		In per cent. of Black.	With or without.	Length of —inches.	Blocked or open.	Screened or run of mine.	Small or full.
952	38	25	Full	46	Without			Screened	Full
900.2	38	25	Full	46	Without			R. of M.	Full
900.10	38	25	Full	46	With	33	Open	R. of M.	Full
900.11	38	25	Full	34	With	50	Open	R. of M.	Full
900.12	38	25	Full	28	With	62	Open	Screened	Small
900.13	38	25	Full	22	With	62	Open	Screened	Small
900.14	38	25	Full	20	With	62	Open	Screened	Full
900.15	38	25	Full	18	With	62	Blocked	Screened	Full
900.16	28	20	Full	2	With	62	Blocked	Screened	Full
900.17	38	25	Full	22	With	62	Blocked	R.of M.*	Full
951	28	20	Full	38	Without			Screened	Full
900.1	28	20	Full	34	Without			R. of M.	Full

* Scalp Level coal.

23. In test 900.16, as already stated (paragraph 11), there was very little smoke. No air was admitted through the arch, but the firedoor was partly open for air admission.

24. There is a decrease in the smoke accompanying the improved evaporation with each increase in the length of the arch, and a further slight decrease when there is no air admitted through the arch. In table 1, the per cent. of black smoke decreases from 46 to 18 per cent. with increases in the length of arch.

25. By the use of the arch the high volatile coal shows smoke four per cent. less black than does the low volatile coal under the same conditions of running.

Conclusions.

Evaporation:

26. The use of the brick arch, with a high volatile coal, such as Penn Gas, results in an increased evaporation, representing an economy in coal of from 12 to 13½ per cent., the indication being that the hollow arch has no advantage over the solid one. (Paragraph 18.)

27. With a low volatile coal, such as Scalp Level, the arch does not appear to be of much benefit. (Paragraph 21.)

Smoke:

28. The admission of air through the arch does not appear to decrease the amount of smoke as obtained with the solid arch. (Paragraph 24.)

29. The smoke from a smoky coal, such as Penn Gas coal, can be reduced by the use of the arch so that it is less than the smoke from a low volatile coal without an arch, but it cannot be made so little as was obtained with low volatile briquettes without an arch. (Paragraph 25.)

General Conclusions:

30. The best results were obtained with the long arch and with air admitted to the firebox through the firedoor. The increase in economy and decrease in smoke followed closely the increase in the length of the arch.

Recommendations.

31. To reduce the amount of black smoke and to improve the economy of the boiler on locomotives where there is con-

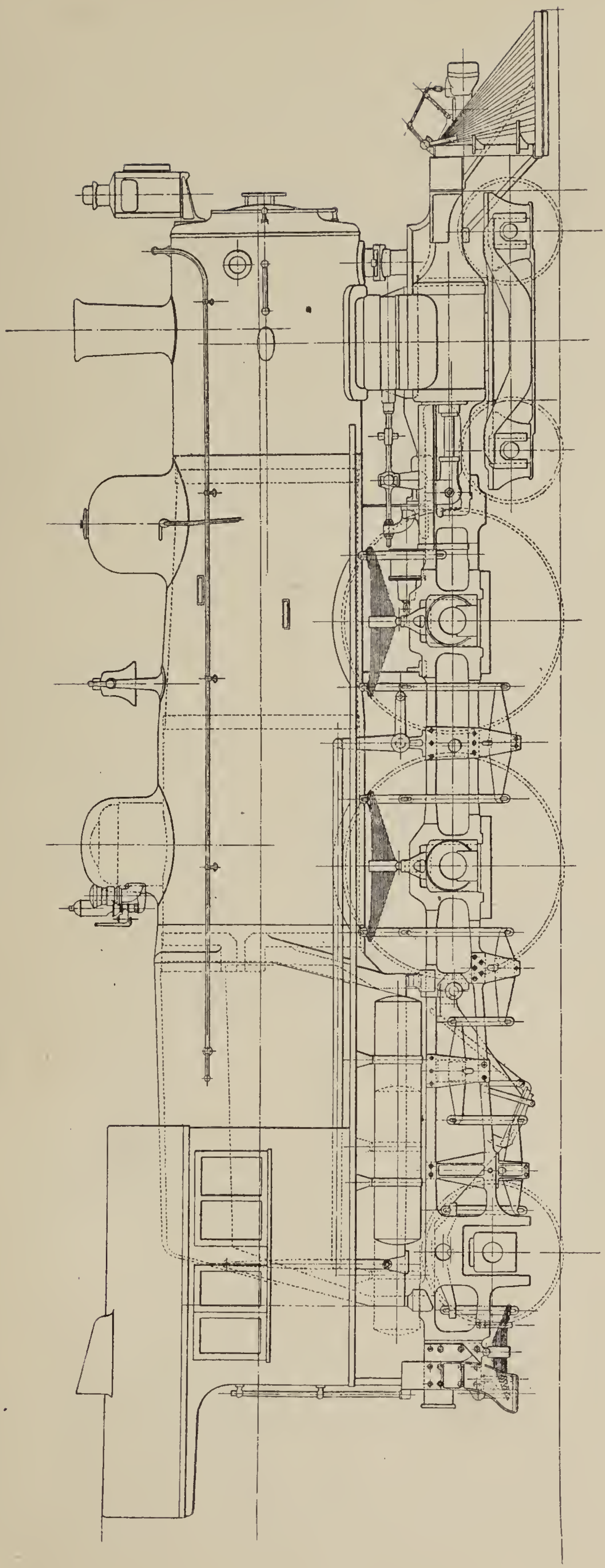
tinuous firing, as on long runs, a solid arch of a length greater than one-half of the firebox should be provided.

32. The reduction of smoke and the saving in fuel depend upon the service in which the locomotive is operated, and this as well as the maintenance of the arch should be given consideration, so as to save the expense of the arch when it is known there can be no material saving by its use.

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
Genl. Supt. Motive Power.

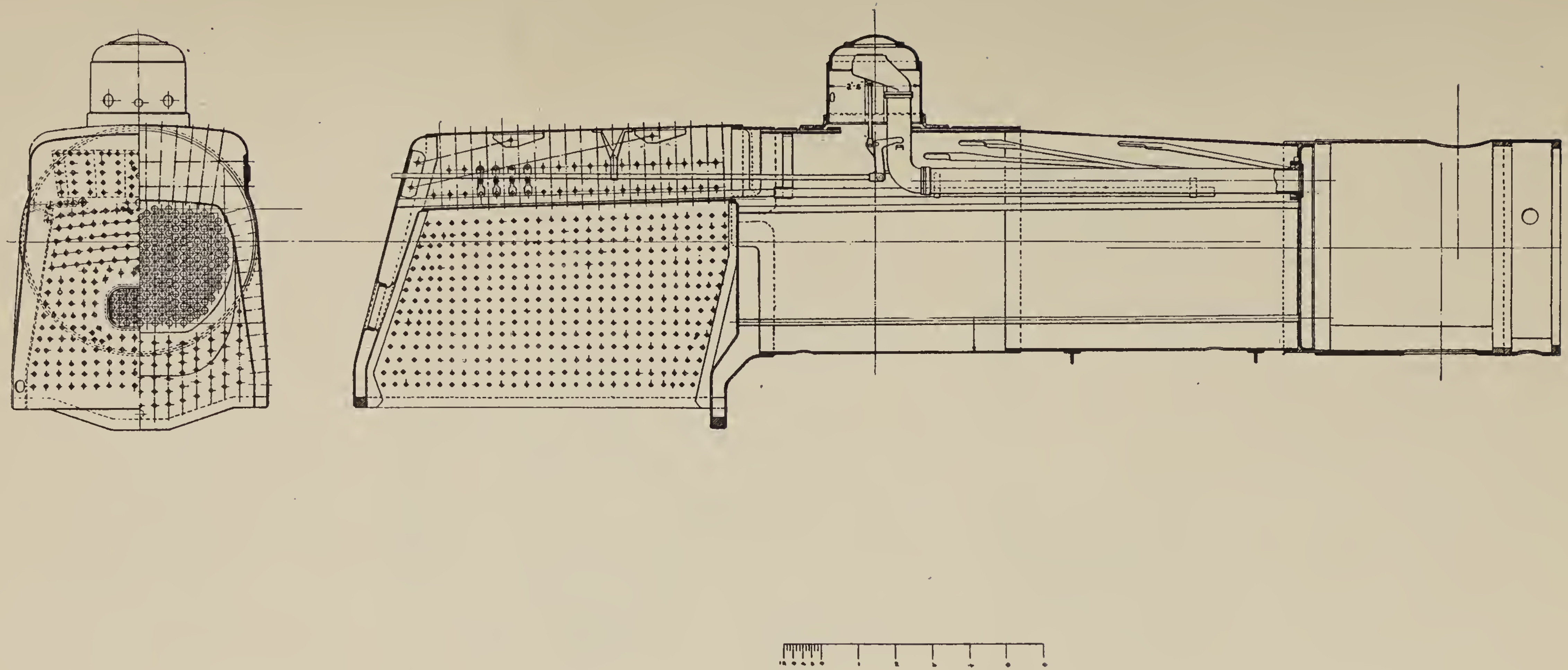
TEST DEPARTMENT,
ALTOONA, PENNA.,
January 28, 1912.



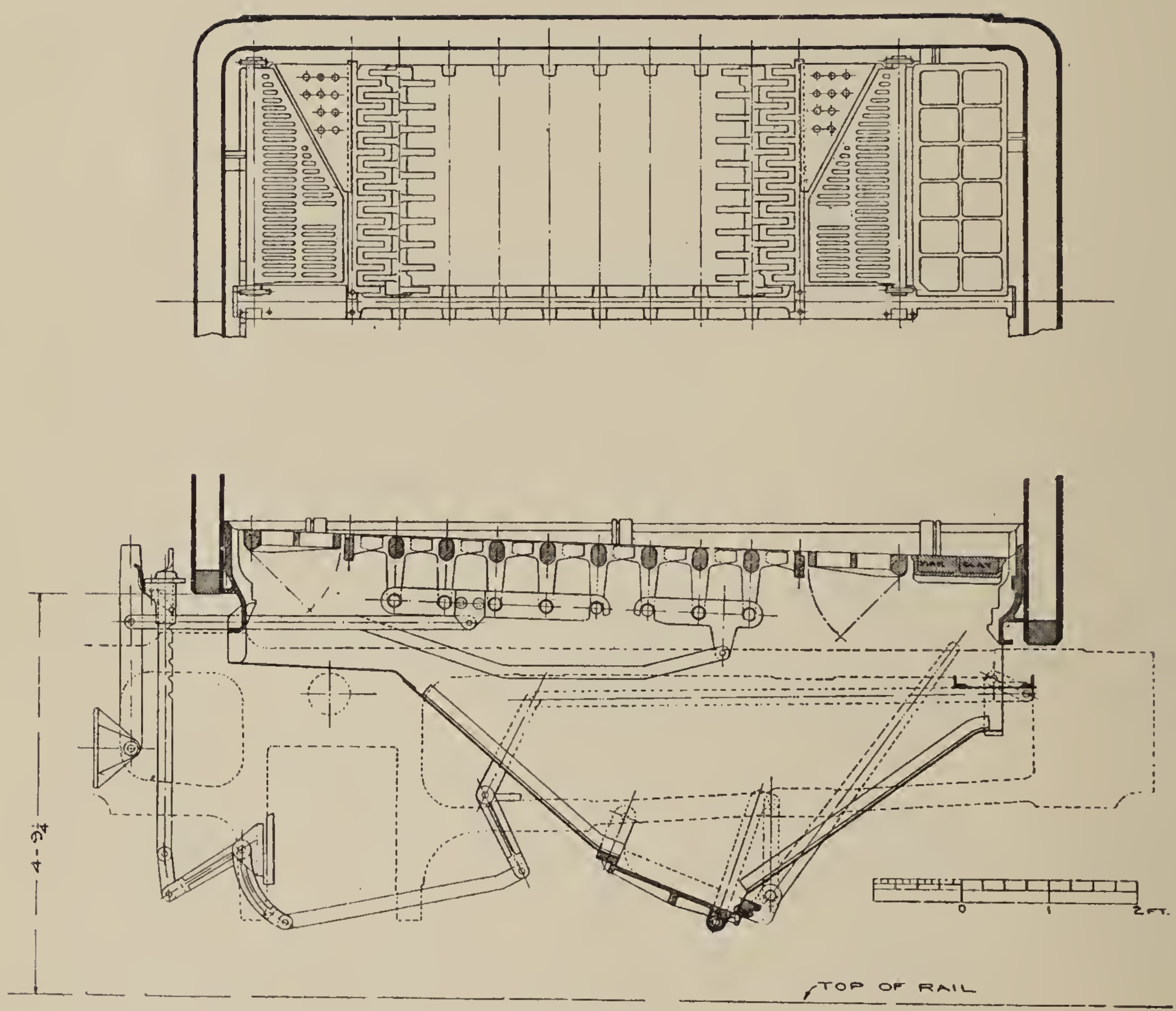
GENERAL ARRANGEMENT OF LOCOMOTIVE.
Fig. 1.

GENERAL DIMENSIONS OF LOCOMOTIVE (CLASS E2a)

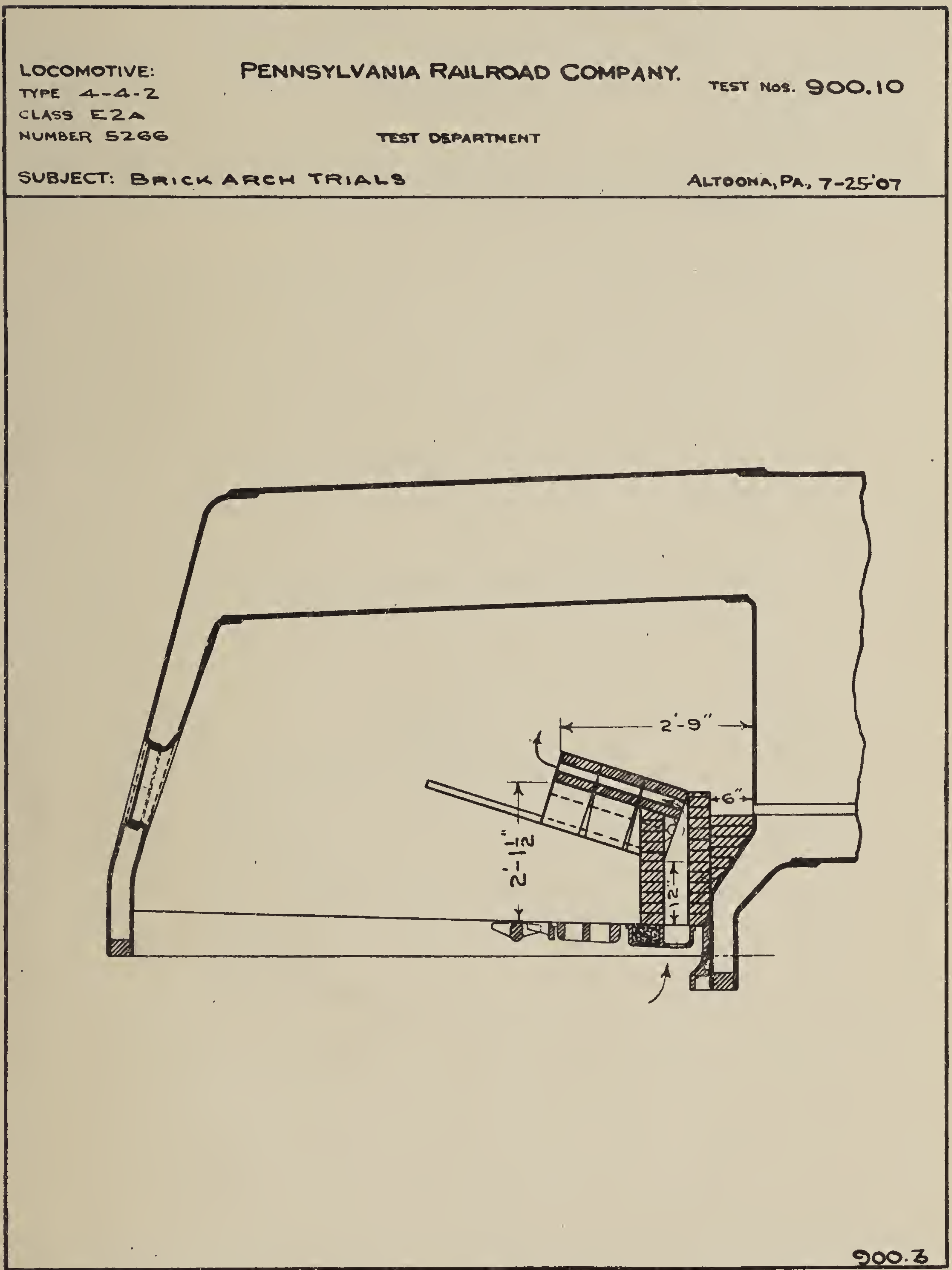
Total weight in working order, pounds	184,167
Weight on drivers, in working order, pounds	110,000
Cylinder (simple) size, inches	$20\frac{1}{2}$ x 26
Diameter of driving wheels, inches	80
Firebox heating surface, square feet	156.86
Heating surface of tubes (water side), square feet	2,471.04
Total heating surface (based on water side tubes), square feet	2,627.90
Total heating surface (based on fire side tubes), square feet	2,319.26
Grate area, square feet	55.5
Boiler pressure, pounds per square inch	205
Valves, type	Wilson double ported, slide
Valve gear	Stephenson
Firebox, type	Wide, Belpaire
Number of tubes	315
Outside diameter of tubes, inches	2
Length of tubes, inches	180



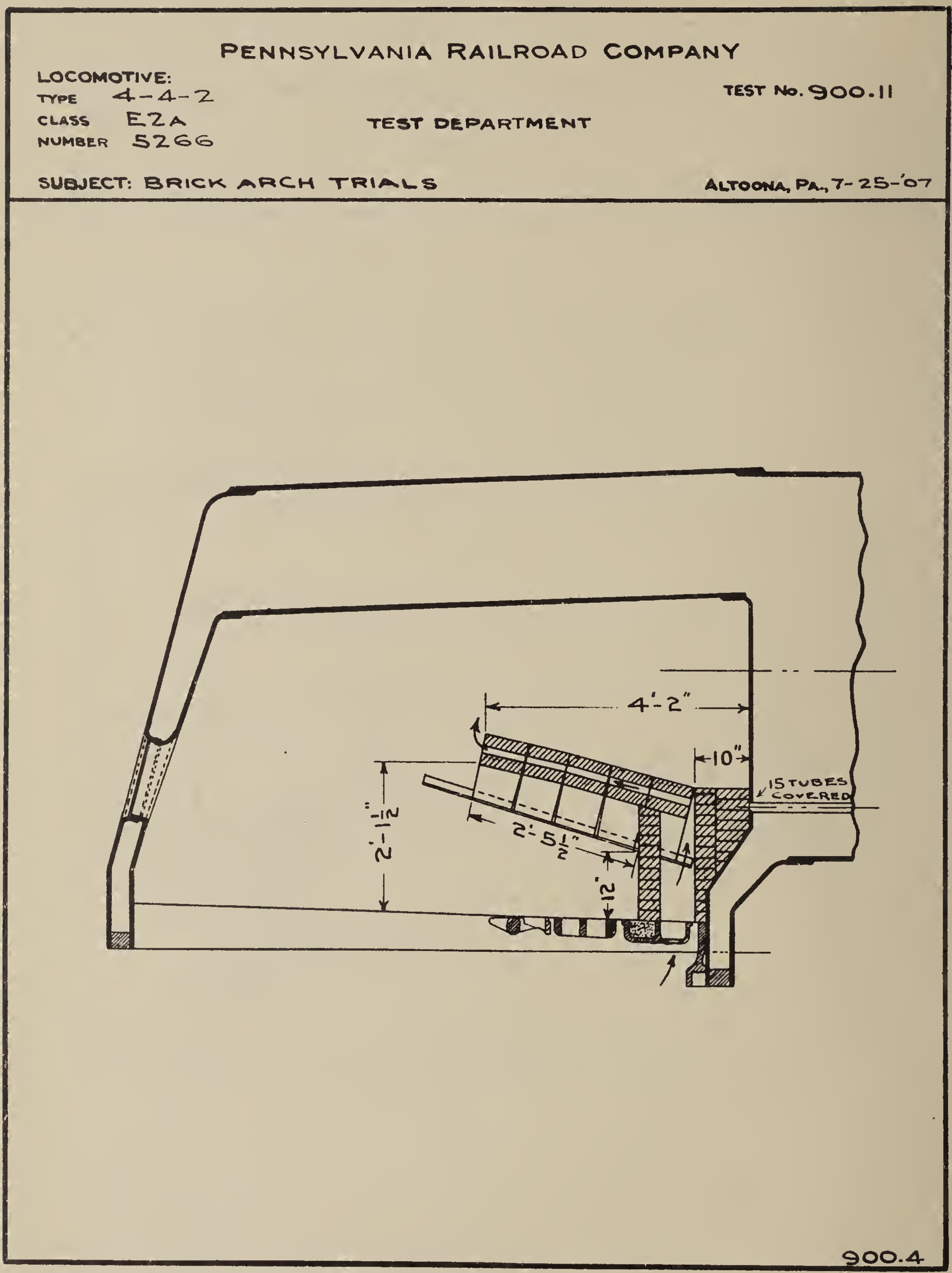
THE BOILER.
Fig. 2.



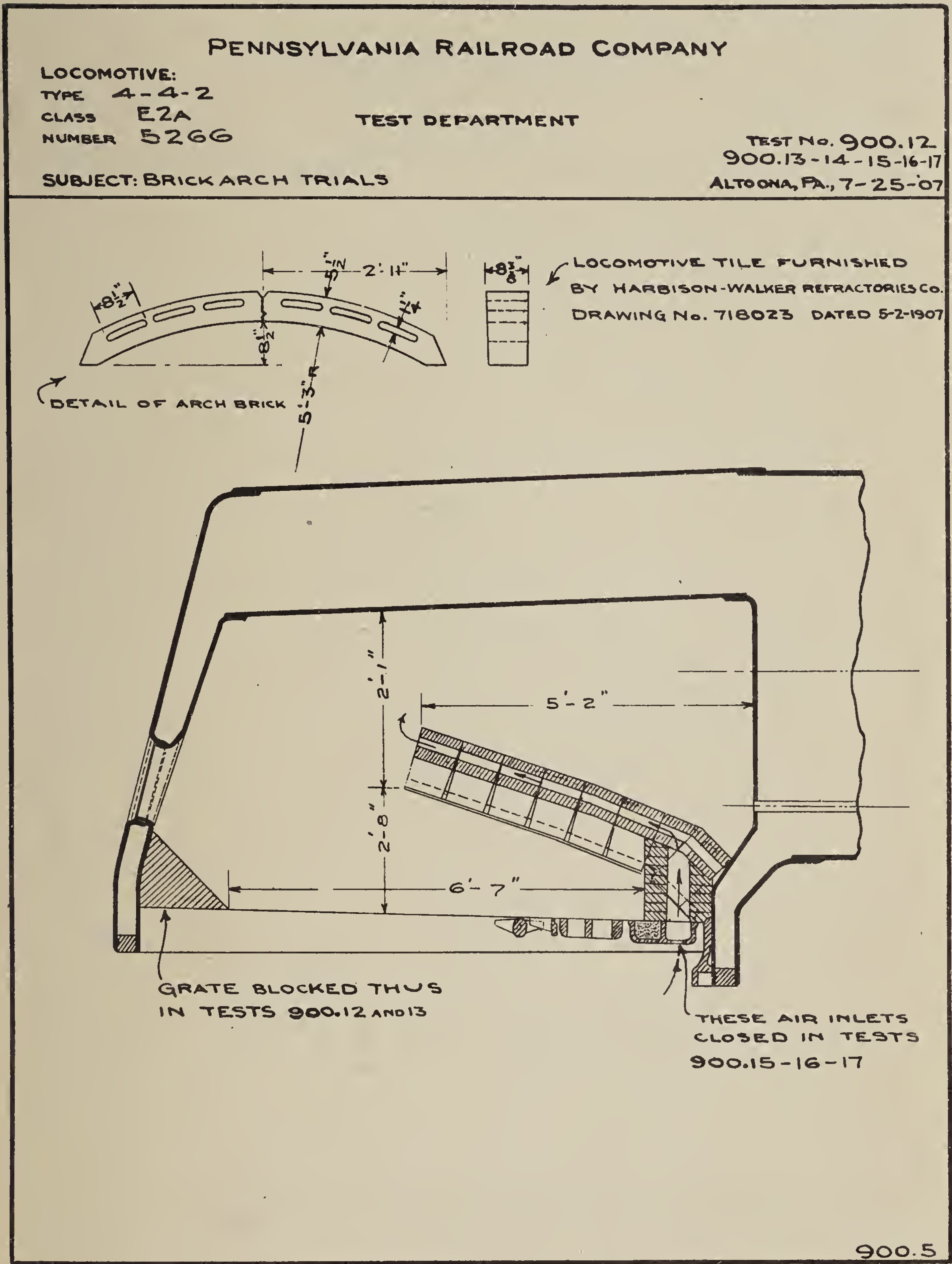
THE GRATE.
It can be shaken in four separate sections. There is a drop grate at the front and rear and a dead grate at the forward end.
Fig. 3.



THE FIRST OR SHORT FORM OF ARCH.
This arch was too small to show much improvement in evaporation or smoke.
Fig. 4.



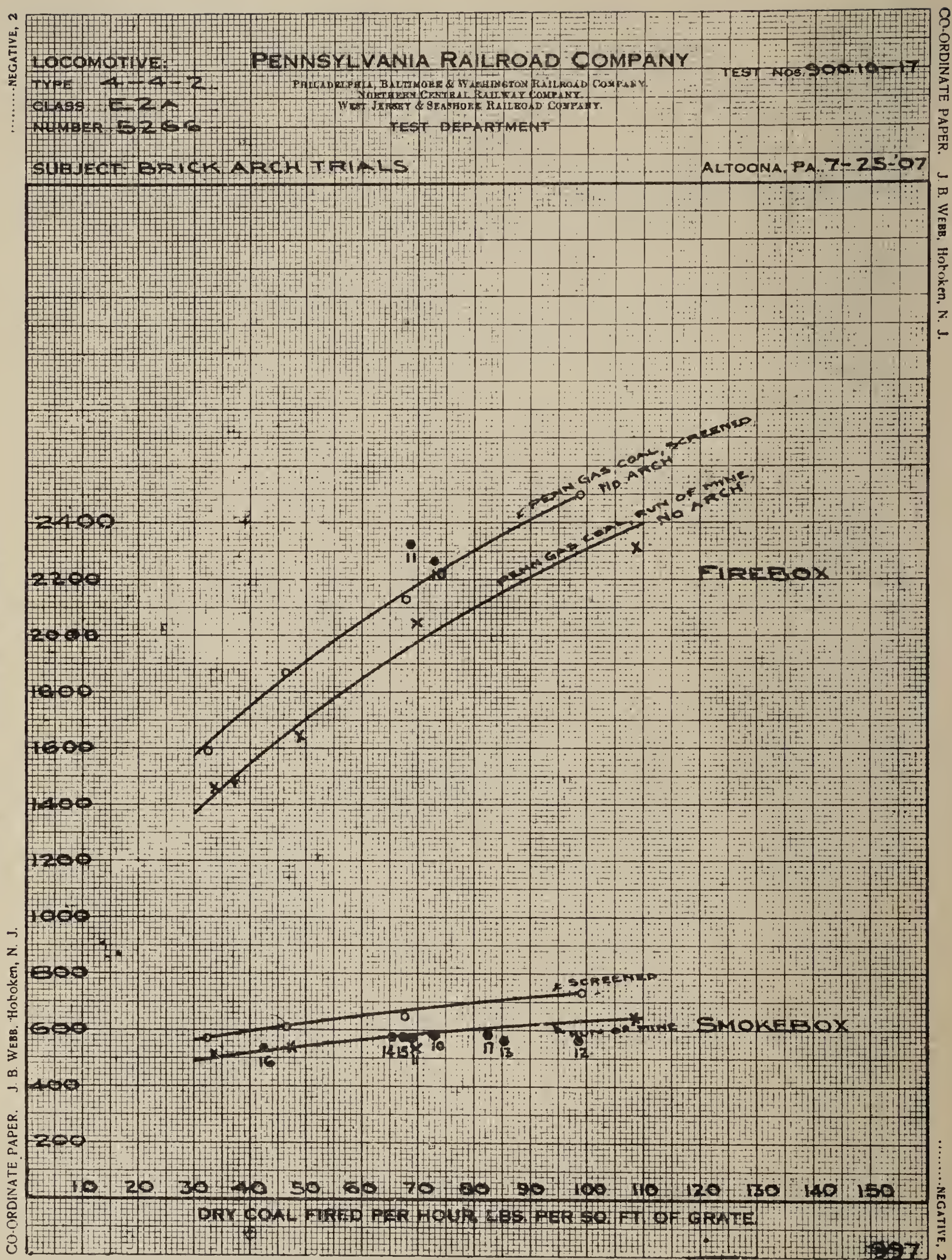
THE SECOND FORM OF ARCH.
It is longer than the first form, and while the lower row of tubes was covered it gave better results than the first arch.
Fig. 5.



THE LONG ARCH WITH THE FRONT END DEPRESSED TO CLEAR THE TUBES.

This arch was used with the air inlets both closed and open and with part of the rear portion of the grate covered with firebrick. This arch shows the best results and there was least smoke when the air passages were closed.

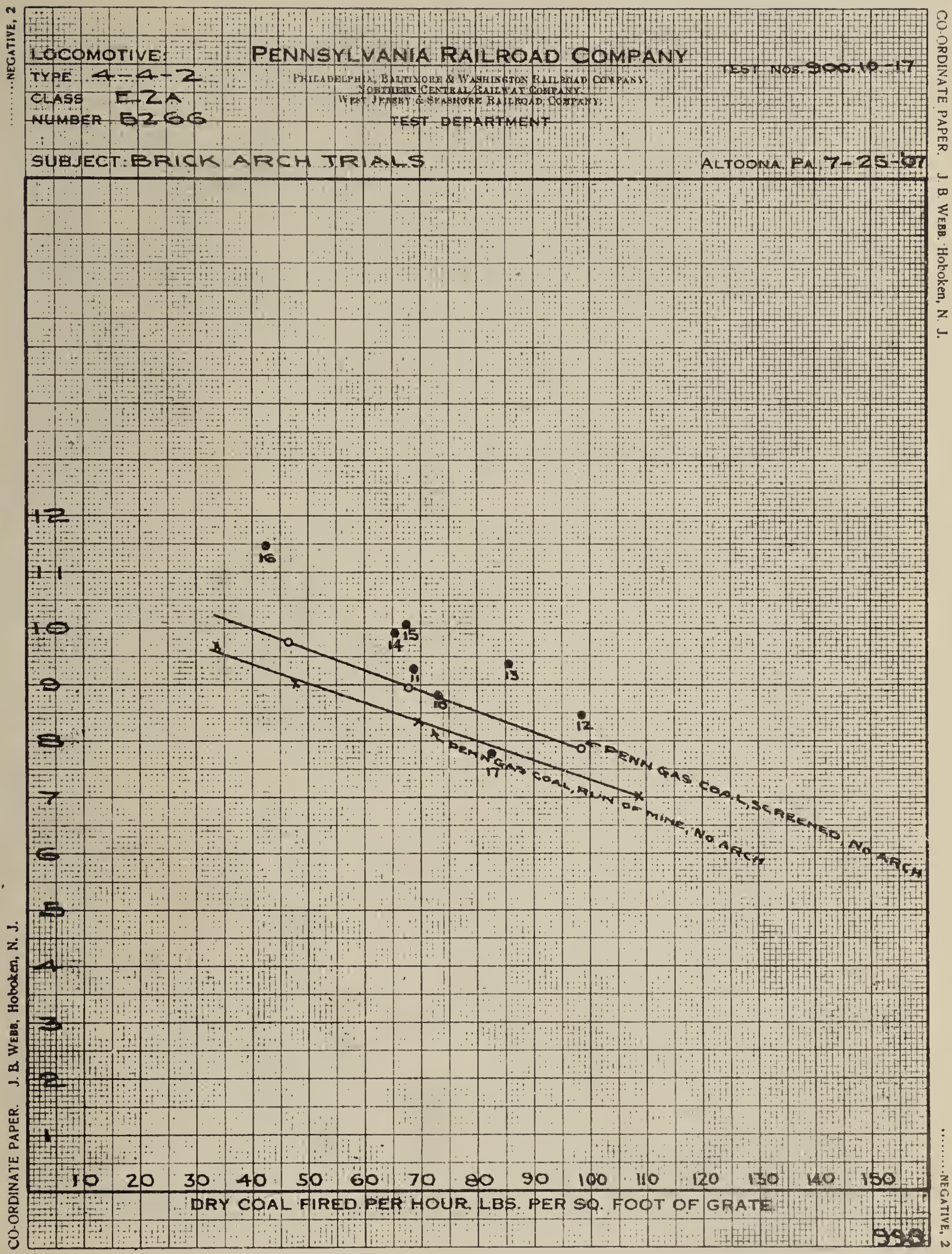
Fig. 6.



TEMPERATURE OF FIREBOX AND SMOKEBOX.

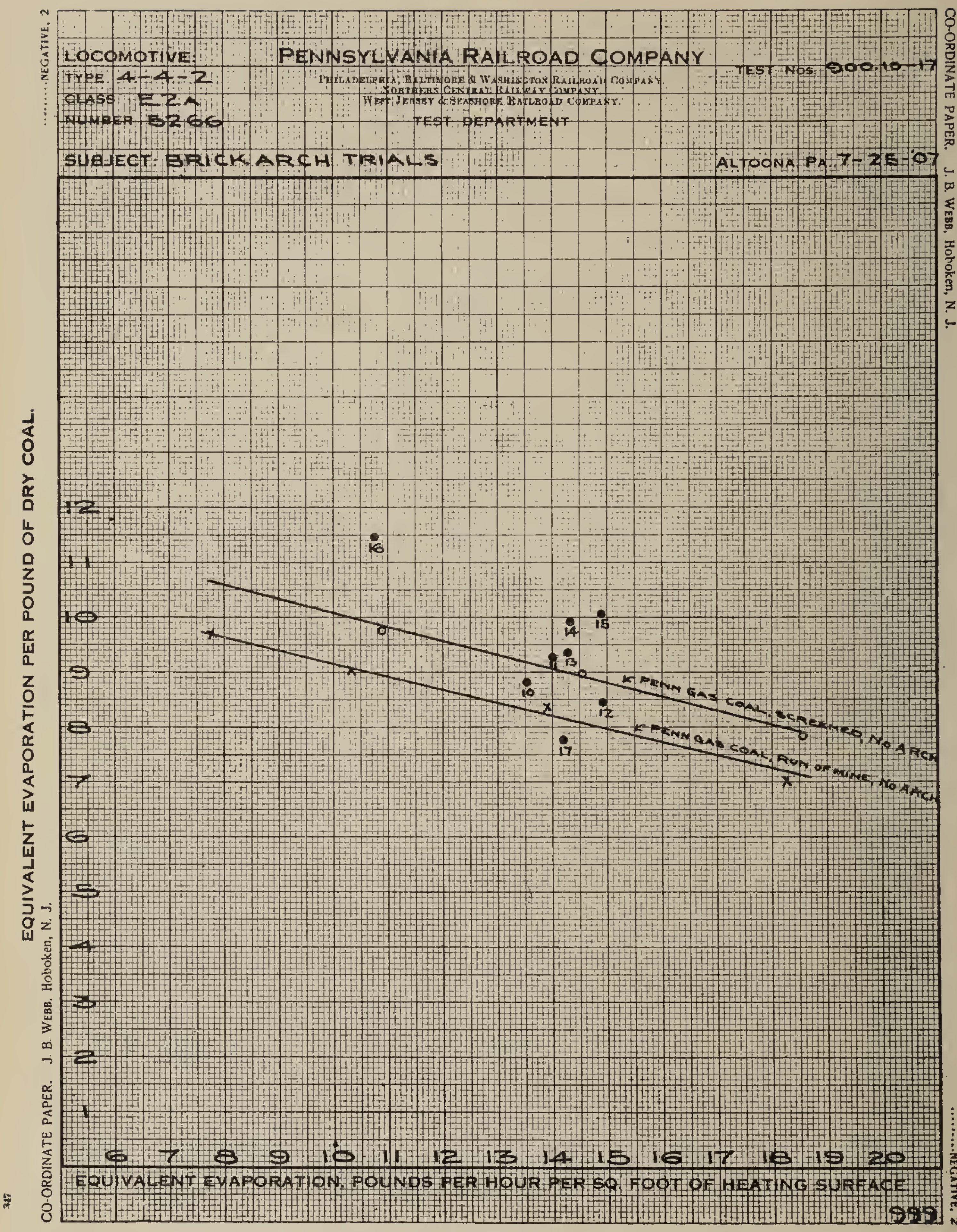
The points with numbers are arch tests. The other points and curves are for tests without arch. Tests 10 and 11 were with run of mine coal, and they show a temperature of firebox about 15 per cent. above that without an arch.

Fig. 7.



EVAPORATION PER POUND OF DRY COAL AND COAL FIRED PER SQUARE FOOT OF GRATE.
The numbered points represent Arch Tests. Those without numbers and the curves are for tests without an arch in the Firebox. Tests 10 and 11 were with run of mine coal, 12 to 16 with screened coal, and 17 was a different coal from the others.

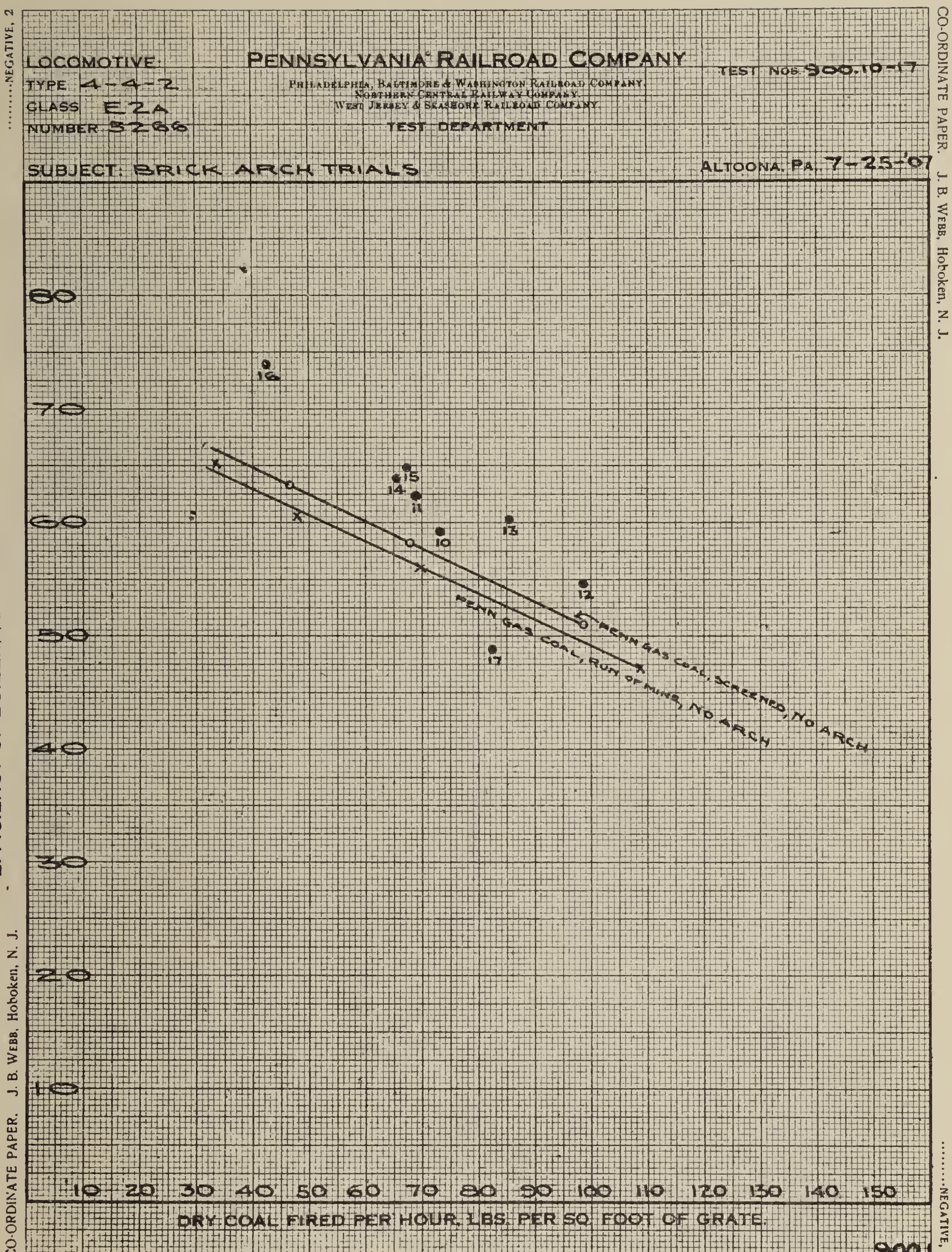
Fig. 8.



EVAPORATION PER POUND OF COAL AND RATE OF EVAPORATION.

The evaporation is about 12 per cent. more per pound of coal with the arch in its best form. Note the low evaporation (point 17) with a low volatile coal.

Fig. 9.



BOILER EFFICIENCY.

The efficiency is increased with the arch, as shown by the points with numbers. Without the arch, the efficiency is from 51 to 64 per cent. With the arch it is from 55 to 74 per cent.

Fig. 10.

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2A
NUMBER 5266

TEST NOS., 952, 900.2
900.10 TO 17

SUBJECT: BRICK ARCH TRIALS

ALTOONA, PA., 8-19-'07

No.	Item	Value
	DRIVING WHEELS	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	ENGINE TRUCK WHEELS	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS	
16	Diameter, inches	50
	WHEEL BASE, FEET	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels	56.13
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	37167
21	" 1st Drivers	53334
22	" 2d "	56667
23	" 3d "	—
24	" 4th "	—
25	" 5th "	—
26	" Trailers	37000
27	Total	184167
28	" on Drivers	110001
	CYLINDERS	
	Diam. and Stroke, H. P.	20.5X26
	" " " L. P.	—
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.7
41	" " Crank "	12.1
42	" Left, Head "	12.4
43	" " Crank "	11.9
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	RECEIVER, CUBIC FEET	
48	Volume Right Side	—
49	" Left "	—
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	19.87
51	" " Width	1.48
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	19.84
67	" " Width	2.98
70	L. P. " Length	—
71	" " Width	—

No.	Item	Value
	PISTON RODS, DIAMETER INCHES	
74	High Pressure	3.472
76	Low "	—
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	—
80	Low "	—
	VALVES	
82	Type	DOUBLE PORTED BAL. SLIDE
83	Design	AMERICAN BAL. VALVE CO.
84	Per Cent. Balanced	75.7
85	Type of Valve Motion	STEPHENSON
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	7.0
88	Low " "	—
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	1.5
94	Low " "	—
	INSIDE LAP OF VALVE	
98	High Pressure, inches	NEGATIVE .16
102	Low " "	—
	BOILER	
113	Type	BELPAIRE WIDE FIRE-BOX
114	Outside Diam. 1st Ring	67.0
	TUBES	
115	Number	315
116	Outside Diam., inches	2.0
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	FIREBOX, INSIDE, INCHES	
132	Length	114.0
133	Width	68.0
137	Air Inlets to Ashpan, sq. ft.	6.3
	GRATES	
144	Type	ROCKING FINGER.
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

No.	Item	Value
	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, " "	156.86
157	" " Superh'r, " "	—
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	338.6
161	Steam " " "	109.9
	EXHAUST NOZZLE	
162	Double or Single	SINGLE
163	Size, inches	5.625
167	Area, sq. inches	24.85
	REVERSE LEVER	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	—
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

THE ABOVE ITEMS SHOW THE NORMAL DIMENSIONS OF THE LOCOMOTIVE WITH FULL GRATE AREA

*USED IN CALCULATIONS

DIMENSIONS OF LOCOMOTIVE 5266.

M. P. 394 A—Sixth Sheet
8 x 10½

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PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2A
NUMBER 5266

FUEL: PENN GAS AND SCALP LEVEL COAL

SUBJECT: BRICK ARCH TRIALS

ALTOONA, PA., 8-19-07

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	ARCH OR NO ARCH	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
952	160-25-F	2.50	38.02	FULL		No ARCH	201.9	3.8	.2	14864	48
900.2	160-25-F	2.50	37.65	"		No ARCH	201.5	4.7	.2	14360	100
900.10	160-25-F	2.17	37.65	"		ARCH	198.4	4.7	.2	14360	135
900.11	160-25-F	2.50	37.65	"		"	198.9	4.7	.2	14360	86
900.12	160-25-F	1.00	37.65	"		"	203.1	5.3	.2	14972	144
900.13	160-25-F	2.50	37.65	"		"	200.6	5.3	.2	14972	140
900.14	160-25-F	2.00	37.65	"		"	203.0	5.0	.2	14972	79
900.15	160-25-F	1.50	37.65	"		"	203.7	3.8	.2	14972	120
900.16	120-20-F	2.00	28.24	"		"	202.2	3.0	.1	14972	43
900.17	160-25-F	2.00	37.65	"		"	202.2	5.2	.2	15402	302

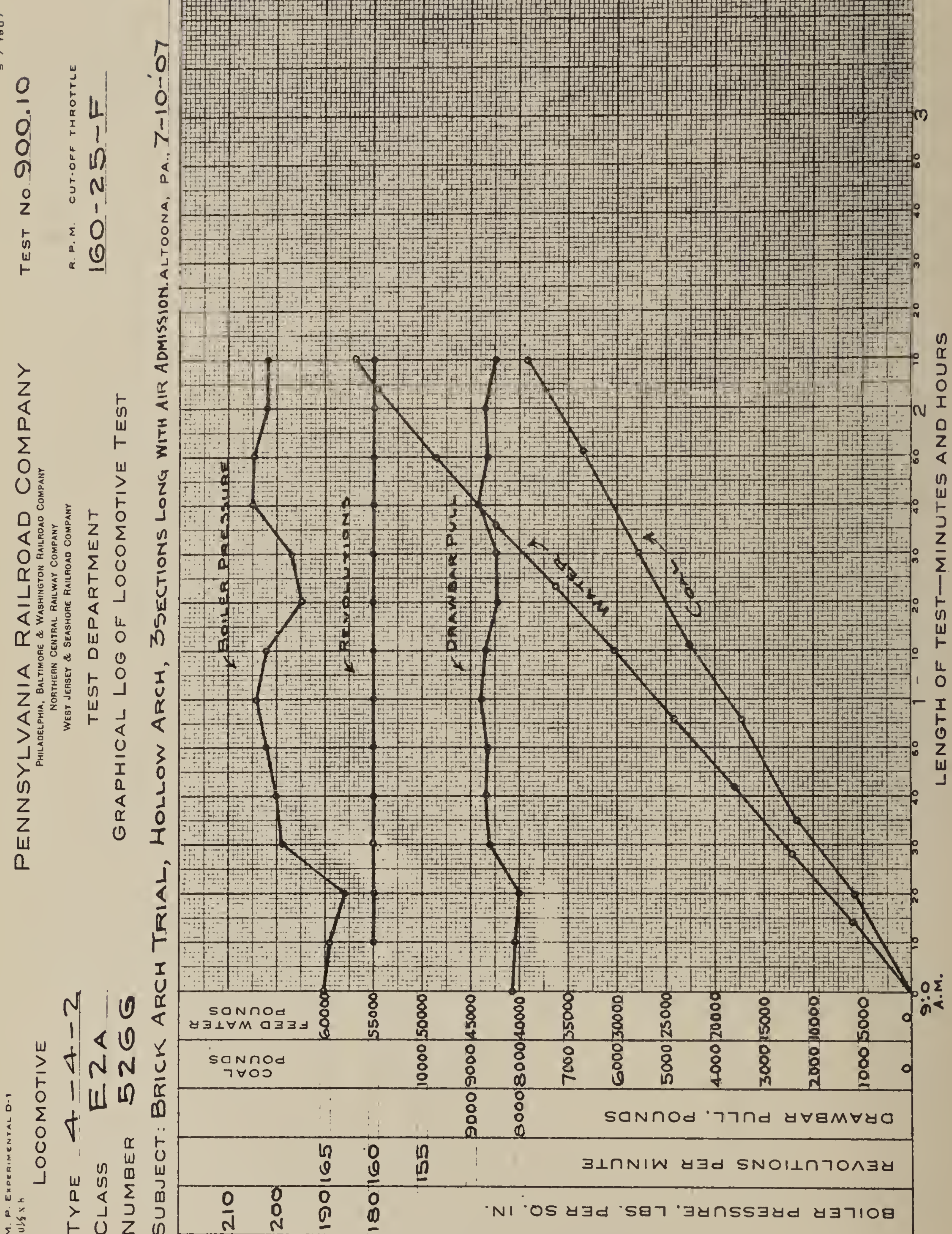
TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Equivalent Evaporation: Per Hour per Sq. Ft. of Fire Heating Sur.	Equivalent Evaporation: Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	SMOKE NUMBER	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
952	3768	67.89	27598	33764	14.56	8.96	978.7	58.22	2.3		
900.2	3864	69.62	26829	32232	13.90	8.34	934.3	56.09	2.3		
900.10	3567	72.95	26213	31384	13.53	8.80	909.7	59.19	2.3		
900.11	3357	68.65	26034	31144	14.06	9.28	902.7	62.41	1.7		
900.12	3905	98.86	27683	33045	14.92	8.46	957.8	54.57	1.4		
900.13	3374	85.42	26430	31579	14.26	9.36	915.3	60.38	1.1		
900.14	3201	65.46	26546	31720	14.32	9.91	919.4	63.93	1.0		
900.15	3286	67.20	27684	33011	14.90	10.05	956.9	64.83	.9		
900.16	2080	42.54	20009	23838	10.76	11.46	691.0	73.93	.1		
900.17	4037	82.56	26362	31446	14.20	7.79	911.5	48.85	1.1		

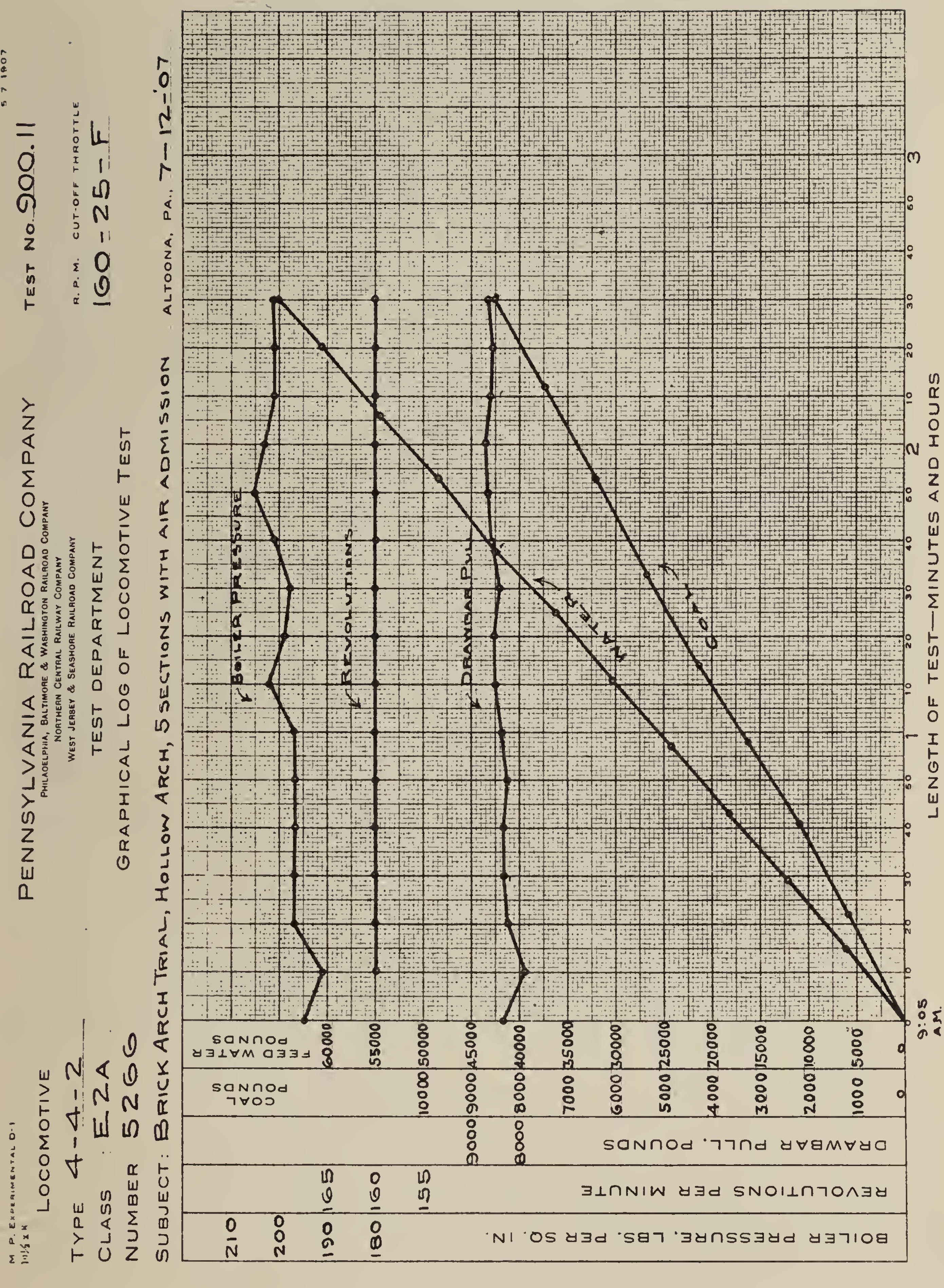
TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	LENGTH OF ARCH	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	KIND OF COAL
	214	379	380	381		265	383	384	385	398	399	
952					—	8768	888.9	4.24	30.74		4.04	PENN GAS
900.2					—	8947	898.5	4.30	29.55		4.12	" "
900.10					2'-9"	8579	861.5	4.14	30.12		4.28	" "
900.11					4'-2"	8492	852.8	3.94	30.22		4.50	" "
900.12					5'-2"	8822	885.9	4.41	30.92		3.85	" "
900.13					5'-2"	8633	866.9	3.89	30.18		4.37	" "
900.14					5'-2"	8762	879.9	3.64	29.86		4.67	" "
900.15					5'-2"	8904	894.1	3.68	30.65		4.62	" "
900.16					5'-2"	7783	586.1	3.55	31.28		4.79	" "
900.17					5'-2"	8998	903.6	4.47	28.86		3.70	SCALP LEVEL

Table 2.

RESULTS OF TESTS WITH AND WITHOUT ARCH.

Tests 900.2, 900.10, 900.11 and 900.17 were made with run of mine coal; the others with screened coal. The tests were from one to two and one-half hours long.


M. P. Experimental D-1
PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 900.10
R.P.M. CUT-OFF THROTTLE
160-25-F
LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266
SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 3 SECTIONS LONG WITH AIR ADMISSION. ALTOONA, PA., 7-10-'07
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
LENGTH OF TEST—MINUTES AND HOURS
9:0 A.M.


M. P. Experimental D-1
Locomotive
Type 4-4-2
Class E2A
Number 5266
Subject: Brick Arch Trial, Hollow Arch, 5 sections with air admission
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 900.11
R. P. M. Cut-off Throttle
160 - 25 - F
Altoona, Pa., 7-12-'07
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Boiler Pressure, Lbs. per sq. in.
Revolutions per minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Length of Test—Minutes and Hours
9:05 A.M.

M. P. Experimental D-1
10½ x 8

5 7 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

Test Department

Graphical Log of Locomotive Test

Locomotive

Type 4-4-2

Class E2A

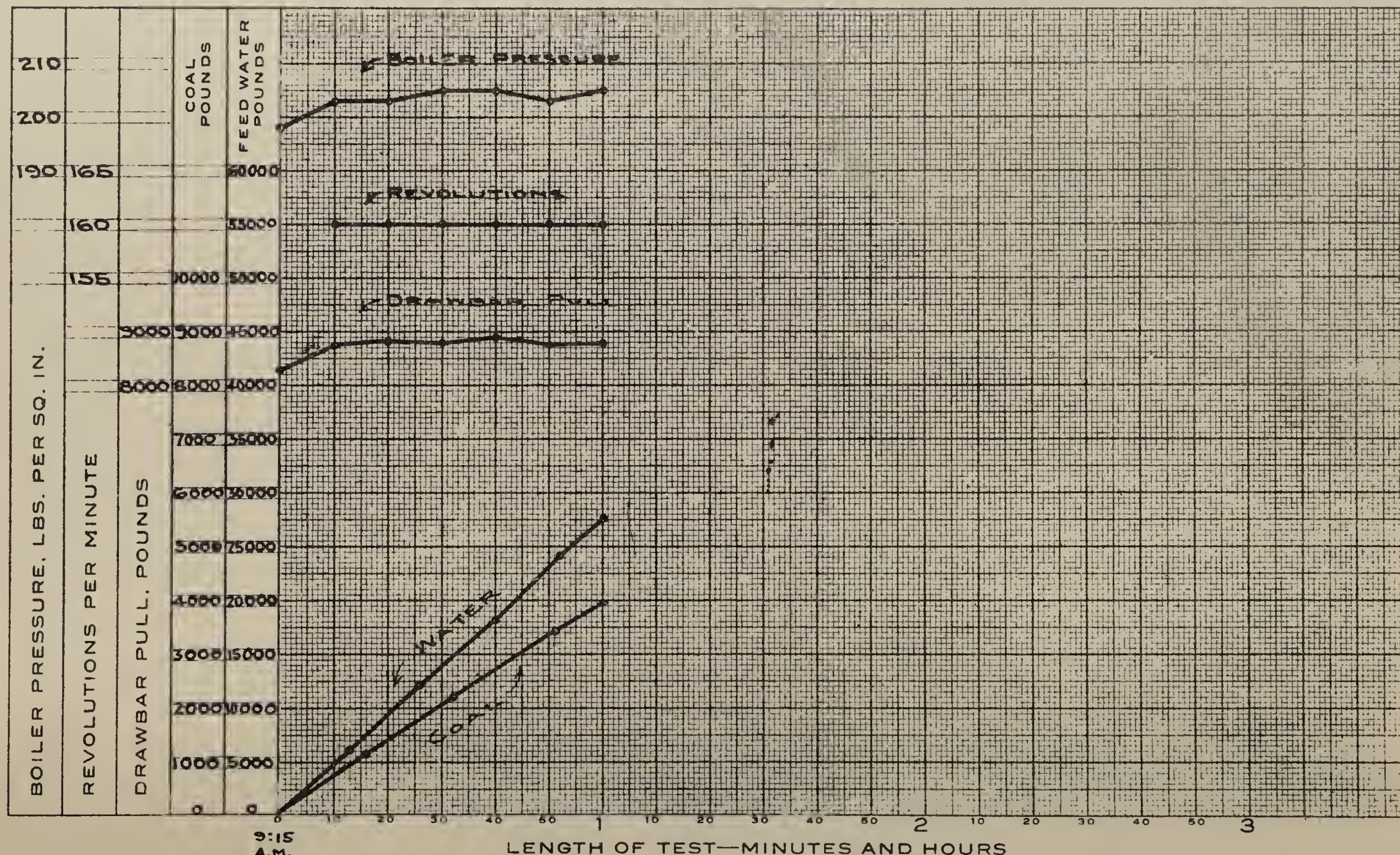
Number 5266

Test No. 900.12

R. P. M. Cut-off Throttle

160-25-F

Subject: Brick arch trial, Hollow arch, 7 sections with air admission, back end of grate blocked. Altoona, Pa., 7-18-'07



M. P. Experimental D-1
10½ x 8

5 7 1907

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

GRAPHICAL LOG OF LOCOMOTIVE TEST

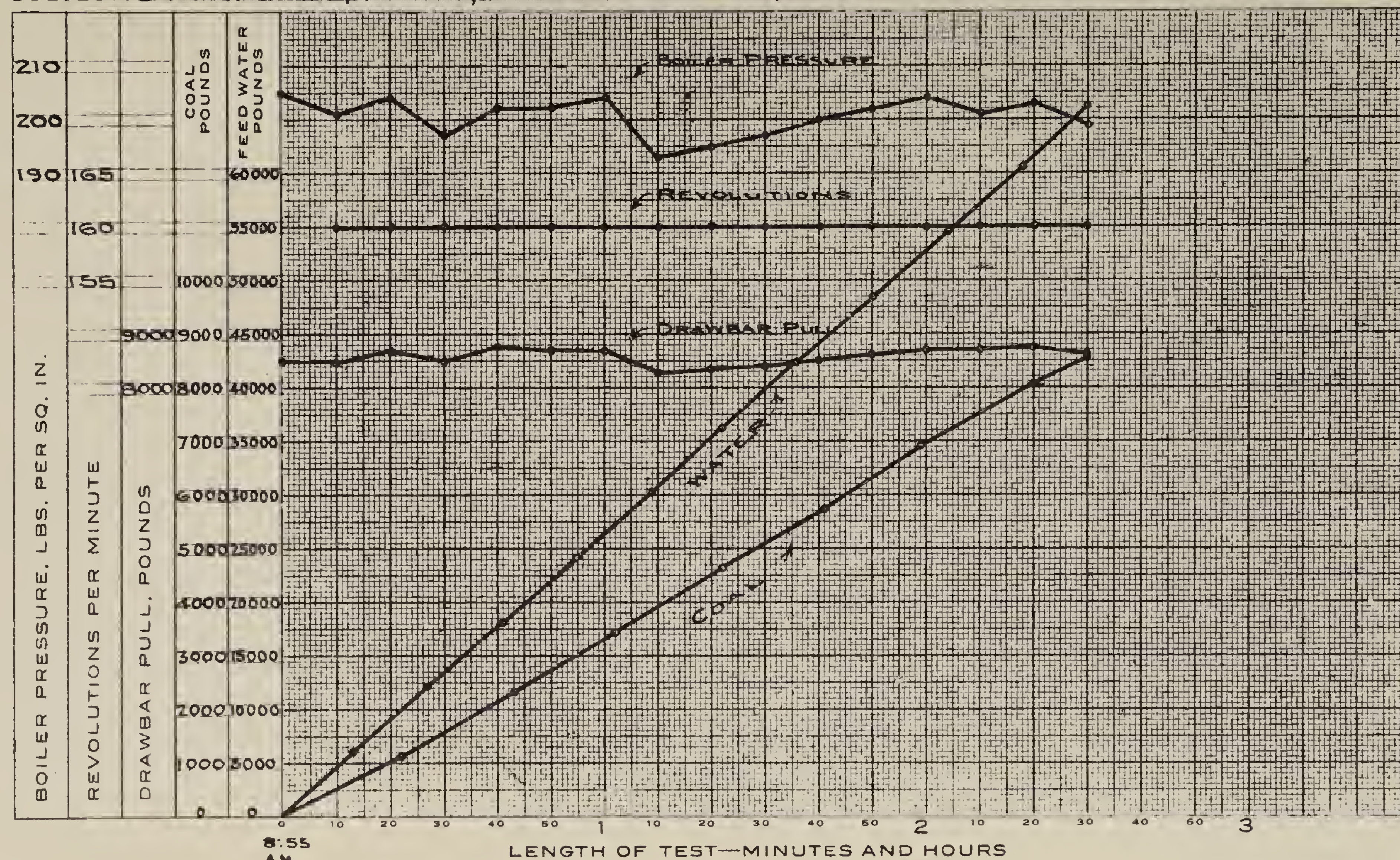
LOCOMOTIVE

TYPE 4-4-2
CLASS E2A
NUMBER 5266

TEST NO. 900.13

R. P. M. CUT-OFF THROTTLE
160-25-F

SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 7 SECTIONS WITH AIR ADMISSION, GRATE BLOCKED AT BACK END ALTOONA, PA., 7-19-'07



M. P. Experimental D-1
10½ x 8

LOCOMOTIVE

TYPE 4-4-2

CLASS E2A

NUMBER 5266

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

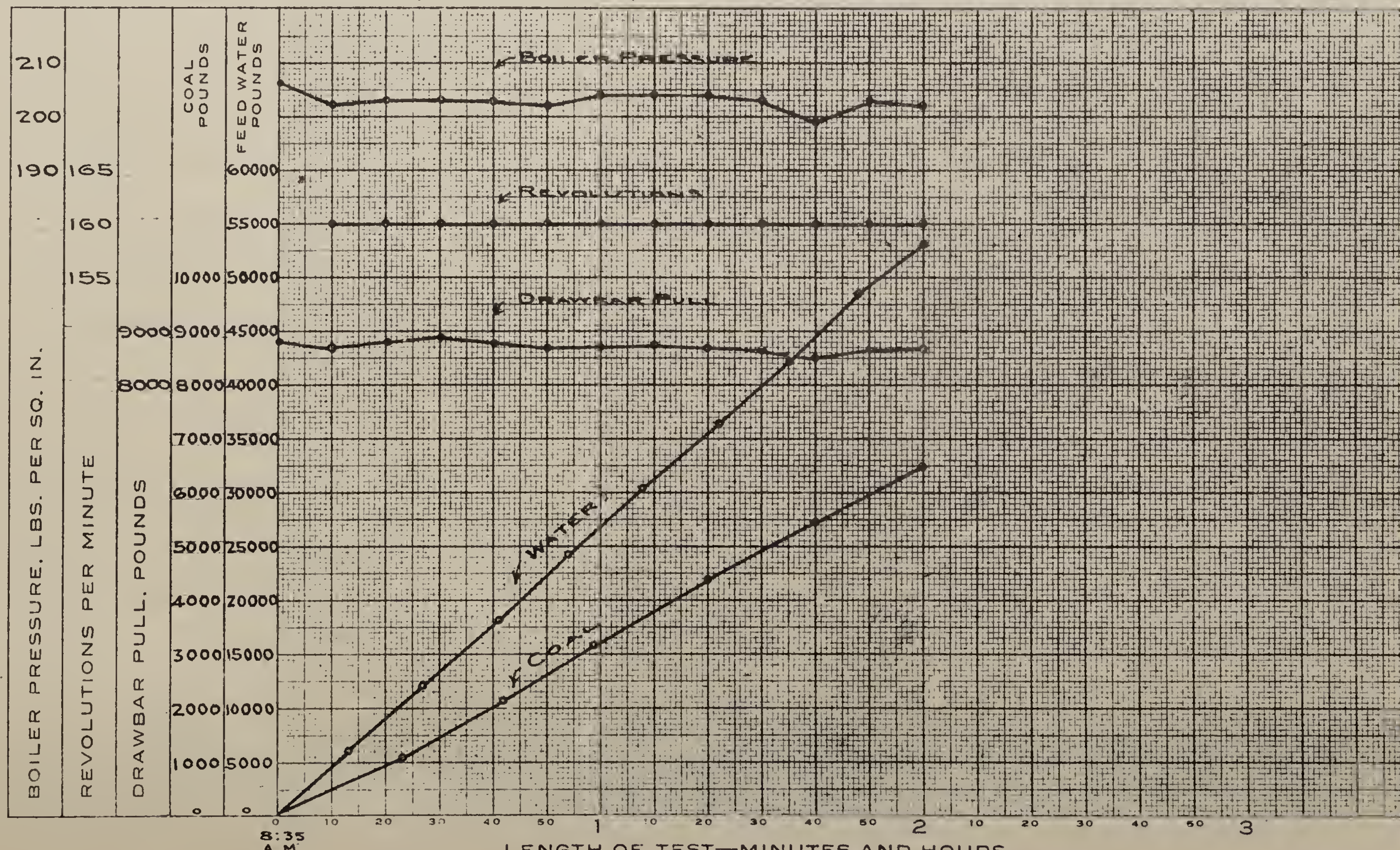
GRAPHICAL LOG OF LOCOMOTIVE TEST

5 7 1907

TEST NO. 900.14

R. P. M. CUT-OFF THROTTLE
160-25-F

SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH, 7 SECTIONS WITH AIR ADMISSION ALTOONA, PA., 7-20-'07



M. P. Experimental D-1
10½ x 8

5 7 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

Test Department

Graphical Log of Locomotive Test

Locomotive

Type 4-4-2

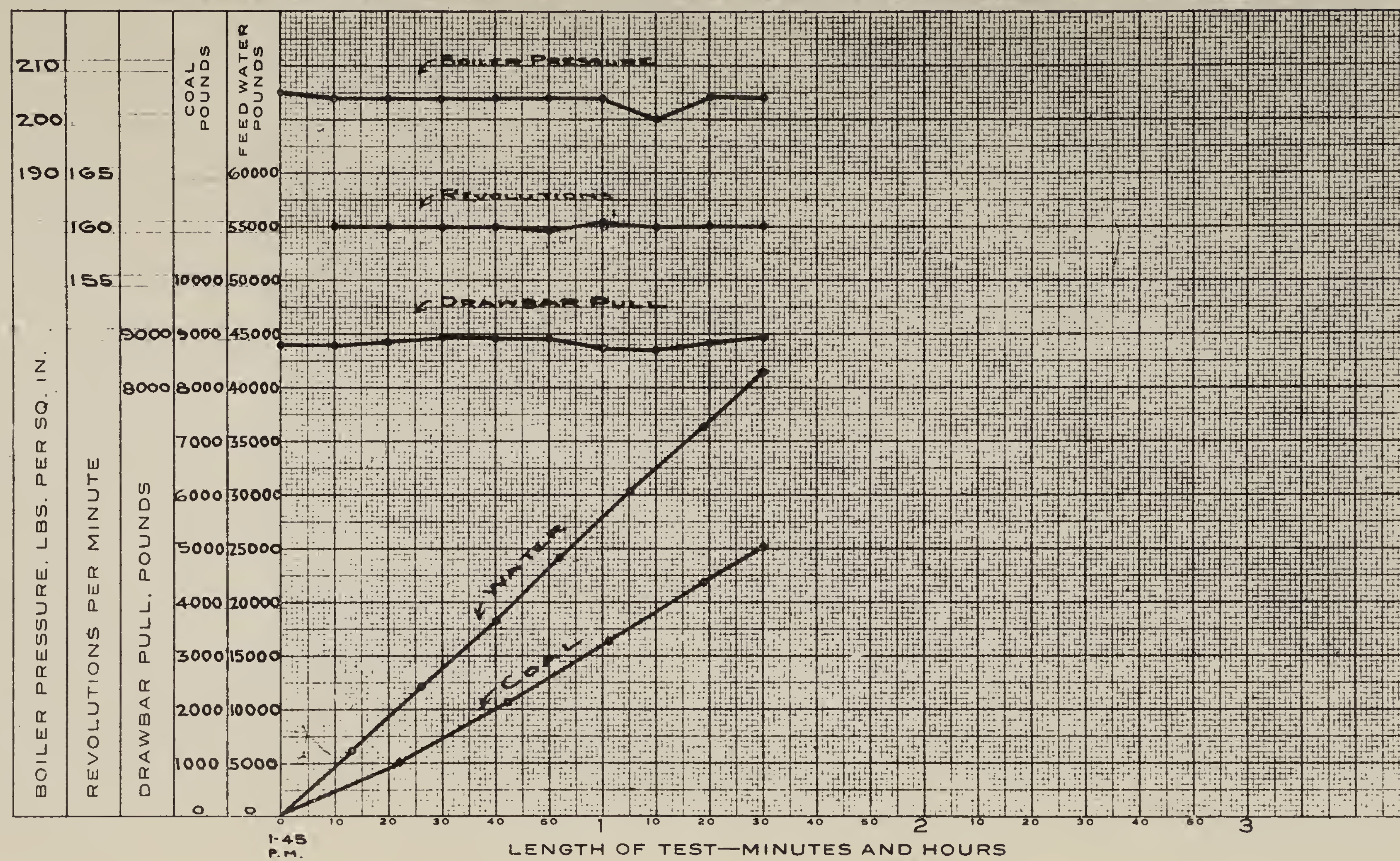
Class E2A

Number 5266

Test No. 900.15

R. P. M. Cut-off Throttle
160-25-F

Subject: Brick Arch Trial. Hollow Arch. 7 Sections Long without Air Admission. Altoona, Pa. 7-22-'07



M. P. Experimental O-1
10½ x 8

5 7 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

Test Department

Graphical Log of Locomotive Test

Locomotive

Type 4-4-2

Class E2A

Number 5266

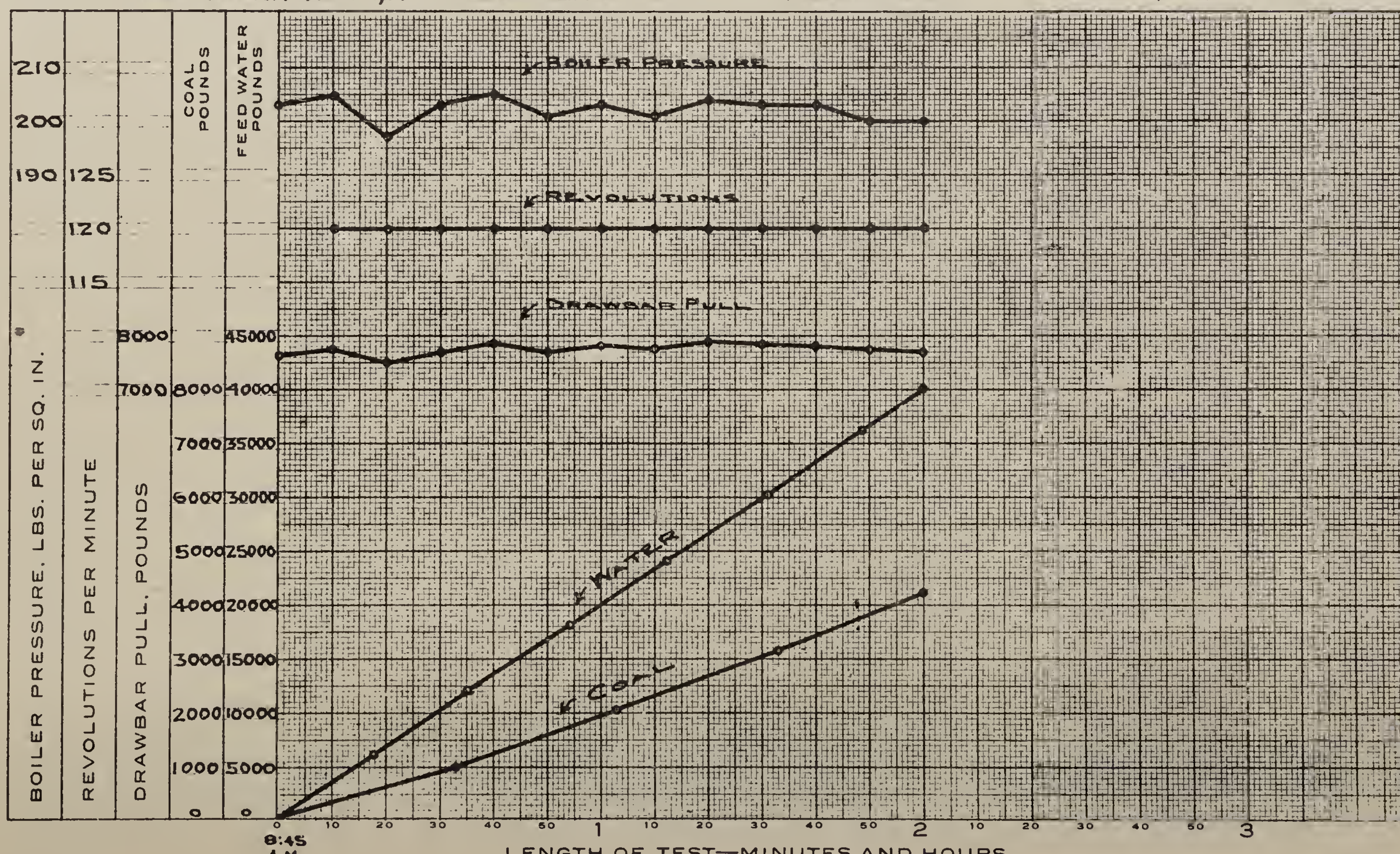
Test No. 900.16

R. P. M. Cut-off Throttle

120-20-F

Subject: Brick Arch Trial, Hollow Arch 7 Sections without Air Admission

Altoona, Pa. 7-23-'07



M. P. Experimental D-1
10½ x 8

5 7 1907

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

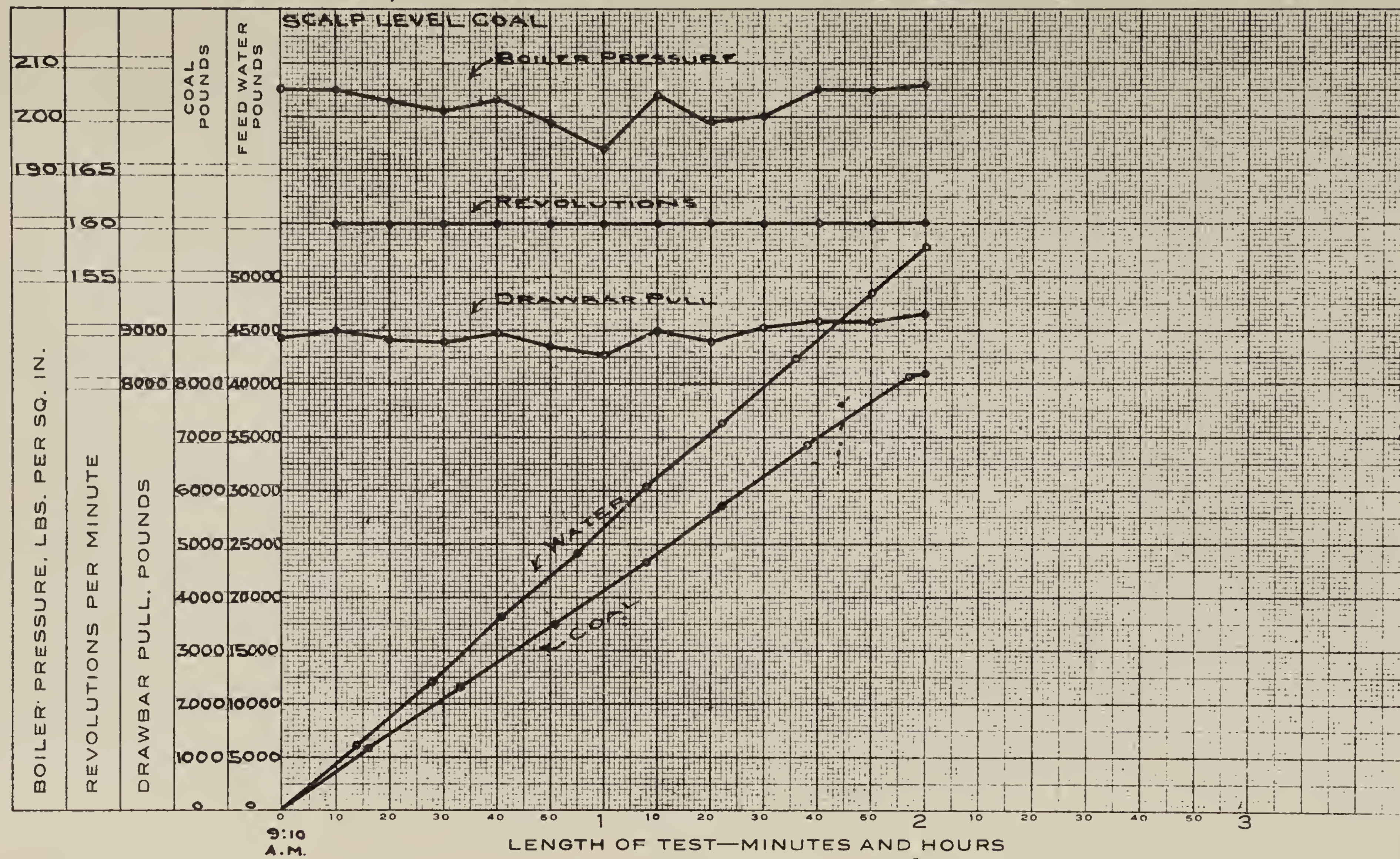
GRAPHICAL LOG OF LOCOMOTIVE TEST

LOCOMOTIVE
TYPE 4-4-2
CLASS E2A
NUMBER 5266

TEST No. 900.17

R. P. M. CUT-OFF THROTTLE
160-25-F

SUBJECT: BRICK ARCH TRIAL, HOLLOW ARCH. 7 SECTIONS WITHOUT AIR ADMISSION   ALTOONA, PA., 7-25-07



THE H6b CLASS LOCOMOTIVE.
The Type of Locomotive used in the Piston Valve Tests.

PENNSYLVANIA RAILROAD COMPANY

LOCOMOTIVE TESTING PLANT

AT

ALTOONA, PENNA.

BULLETIN No. 7 (REVISED)

FORMERLY BULLETIN No. 29

PISTON VALVES

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1912

LOCOMOTIVE TESTING PLANT.

PISTON VALVES.

(Conclusions and recommendations on pages 6 and 7.)

INTRODUCTION.

1. In the tests of piston valves described in this Bulletin some remarkable results were found in steam leakage with one type of valve. Valves of the Company's own make are found to have very substantial advantages in price over valves of outside manufacturers.

2. Two forms of piston valves are in extended use on our locomotives, one the American Semi-plug, as used on the Lines East, and a valve which will be designated the "L" type, much used on the Lines West. Another form of valve is the Stayman Self-expanding Valve. This Stayman valve is not used on our locomotives.

3. While the three valves differ in details of construction, their overall dimensions were alike so that they would be expected to give practically the same distribution of steam in the cylinder. Differences in service were to be looked for in the amount of steam leakage under various conditions of running.

4. Satisfactory service has been obtained with both the American and "L" type form of valve, and these trials were undertaken, not because of defects found in the valves, but in view of the lower first cost and lower repair costs of the "L" type valves, to determine their performance under identical conditions, where the steam and coal used could be accurately measured.

5. The amount of wear and the expense of maintenance of the valves could not be determined on the Testing Plant. These items could be determined only by wearing out the valves in service.

Description of Valves.

The Stayman Valve.

6. The Stayman Self-expanding Piston Valve is shown in the photographs, Figs. 2 and 3. The valve is made up of a section of four and one-half inch, wrought iron, pipe screwed into castings which carry the packing rings. There is a split cast-iron ring fitting on the valve spindle and outside of this ring there is a heavy cast-iron ring divided into three segments. The segments are held together by brass plates and pins. The ring does not come apart when the valve is removed from the valve cages.

7. The wearing surface of the valve ring is $2\frac{3}{4}$ inches wide and has grooves as shown on the drawing, Fig. 5. Besides the valve stem, the heads of the valve are held together by one through bolt. The valve is 12 inches in diameter, $32\frac{1}{4}$ inches long over the packing rings, is made up of 10 principal parts and weighs 188 pounds.

8. The valve was furnished for test by the Cockburn Barrow & Machine Company of New York, N. Y.

The American Valve.

9. The American Balance Valve Company's Semi-plug valve, as shown in the two photographs with the Stayman valve, is of the same design as the one tested, but is larger in diameter. In the tests, however, the valve used was a 12 inch one. The rings of this valve are shown on the drawing, Fig. 4.

10. The American valve is made up of 17 principal parts and weighs 161 pounds, the heads being held together by two bolts, in addition to the valve stem. The rubbing face of the valve is formed by two narrow expanding or snap rings connected by a thin, wide ring having a number of "V" shaped grooves. Under this wide connecting ring there are wedge-shaped rings as shown in Fig. 4, and from the chamber under the wedge rings there are 18 small ports leading to the live steam side of the valve.

11. This is the standard valve for the "H6b" class of locomotive, and is made by the American Balance Valve Company of Jersey Shore, Pa.

The "L" Type Valve.

12. The "L" type valve is shown on the photographs, Figs. 2 and 3 and on the drawing, Fig. 6. It is made up of a section of

8 inch, outside diameter pipe, riveted to steel castings at the ends. The heads also of the "L" type valves were of steel in the valves tested. There are two "L" shaped cast-iron packing or snap rings with a cast-iron separating ring between them. The separating ring is not divided or split.

13. The packing rings are divided and are held from turning by pins on the lower side of the valve spindle. The heads are held in position by the nut on the valve stem, there being no through bolts as in the other two valves. The valve is 12 inches in diameter, $32\frac{1}{4}$ inches long over the packing rings, is made up of 10 principal parts and weighs $137\frac{1}{2}$ pounds. The valves were furnished by the Pennsylvania Lines, Fort Wayne Shops.

Method of Conducting the Tests.

14. Two different "H6b" locomotives had to be used for these tests; first, No. 2860 for the American and Stayman valves, commencing August 9, 1910, and No. 884 for the "L" type and American valves, commencing September 14, 1911, giving a direct comparison of the American with the other two types. The general arrangement of the "H6b" class locomotive is shown in Fig. 1, and the cylinder and valve in Fig. 7.

American Valve.

15. The American valve, as it was found on the locomotive where it had been in use for over two years, having made about 620 runs of from one-half to three hours duration each, was the first to be tested. The valves, and the cages which had been in service as long as the valves, were then removed, new cages put in and the Stayman valve (new) placed in the new cages and a series of tests made. Following this, American valves were again applied (new) and tested likewise without changing the cages.

"L" Type Valve.

16. New "L" type valves were used and new cages were put in the steam chests. Immediately on starting with the "L" type valves one of them was broken. It was found on removing it from the cage that the openings in the valve rings were passing over open ports in the cages. Both valves were then replaced on the valve stems so that the openings in the rings would travel over one

of the bridges on the lower side of the valve cage and no further difficulty was experienced with the valves after this change.

17. With the American Semi-plug valve no special setting of the valve on the stem is necessary, as the opening in the rings will not catch on the port in any position.

18. After eight tests had been made with the "L" type of valves they were removed and the tests duplicated with the American valves in the same cages. These were repaired valves with new packing rings, making them practically new valves.

19. While data had been obtained for the American valve in the first series of tests, on the other locomotive, it was tried again to make a more accurate comparison with the "L" type valve.

20. Each set of new valves was used in preliminary tests during about one week so that they would be in good running condition and well lubricated before the actual tests were made.

21. The American valve is a very satisfactory one from a mechanical standpoint, while the workmanship on the "L" type valves was not as good from their general appearance, and it is possible that the two types of valves, both carefully made, would show the same results. The valves for tests were not selected with any particular care as it was desired to obtain valves as ordinarily used.

Results of Tests.

22. The Stayman valves show remarkably poor results in steam and coal consumption. In these tests they used from 25 to 200 per cent. more steam, and from 44 to 81 per cent. more coal than the American valves.

23. The speeds ranged from $6\frac{1}{2}$ to $26\frac{1}{2}$ miles per hour, and the cut-offs from 20 to 40 per cent. The results of the tests are shown on the diagrams, Figs. 8 to 11, and on tables 1 to 5.

24. There was a slightly lower coal and steam consumption with the American than with the "L" type valve. The diagrams, Figs. 8 to 11, show curves for the three valves on both locomotives. In Fig. 11, the "L" type valve compared with the American valve shows practically the same results.

25. At the speed of 6.6 miles per hour (40 revolutions per minute) and at a cut-off of about 20 per cent. with the American valves, the drawbar pull was 13,283 pounds, as against a pull of

9,114 pounds with the Stayman valves, under the same conditions as nearly as could be maintained, or a loss by the Stayman valves of 4,159 pounds, equivalent to 31 per cent. of the drawbar pull. At $26\frac{1}{4}$ miles per hour, the highest speed of the tests, a similar comparison of the pulls shows a loss of 3,500 pounds or 29 per cent. with the Stayman valves.

26. The fact that the valves were leaking to such an extent was not evident from the sound of the exhaust while the locomotive was in motion. With the locomotive standing the reverse lever was placed in the centre notch and with the driving wheels on each quarter stroke position the throttle valve was opened. Under these conditions there was a heavy blow or valve leak.

Cost of Valves.

27. The first cost of these valves to equip one locomotive is as follows:

American Semi-plug Piston Valves, complete (2 valves)	\$77 00
"L" Type Piston Valves, complete (2 valves)	71 46
Stayman Self-expanding Piston Valves, complete (2 valves)	360 00

28. The cost of renewals of parts most subject to wear, or the rings which are in contact with the valve cages, is as follows:

American Valve (8 snap rings and 4 wide rings)	\$15 96
"L" Type Valve (8 snap rings)	3 04
Difference	\$12 92
Stayman Valve (4 segment rings)	\$180 00

29. The quotations on the Stayman valves are for single valves, while those on the other two are for considerable quantities. The higher price at which the Stayman valve was offered, especially in view of the poor results obtained, made further inquiry as to costs not worth while.

Conclusions.

30. The Stayman piston valves, when in good working order, leak so badly as to seriously limit the hauling power of the locommotive. They used from 25 to 200 per cent. more steam and from 44 to 81 per cent. more coal per unit of power than the standard valves for the "H6b" locomotive.

31. The excessive leakage of this valve is probably due to the rigid construction of the expanding or packing ring. This heavy ring cannot adjust itself to unevenness of the valve cage. This valve is not well adapted to valve cages which are slightly out of alignment at the opposite ends of the steam chest on account of its packing rings being held parallel at all times.

32. The very little difference shown between the "L" type and American valves in steam and coal consumption per unit of power in favor of the American valve, is too small to be given serious consideration (Paragraph 24).

33. There is, on the other hand, a slight advantage in the cost and weight of the complete "L" type over the American valve, and a very large saving possible in the cost of the renewal parts on account of the simplicity of the parts of the "L" type valves (Paragraphs 27, 28 for cost, 10 and 13 for weight).

34. The "L" type of valve may be manufactured without any liability for patent infringement about which there might be some question, in the cases of both the American and Stayman valves.

RECOMMENDATIONS.

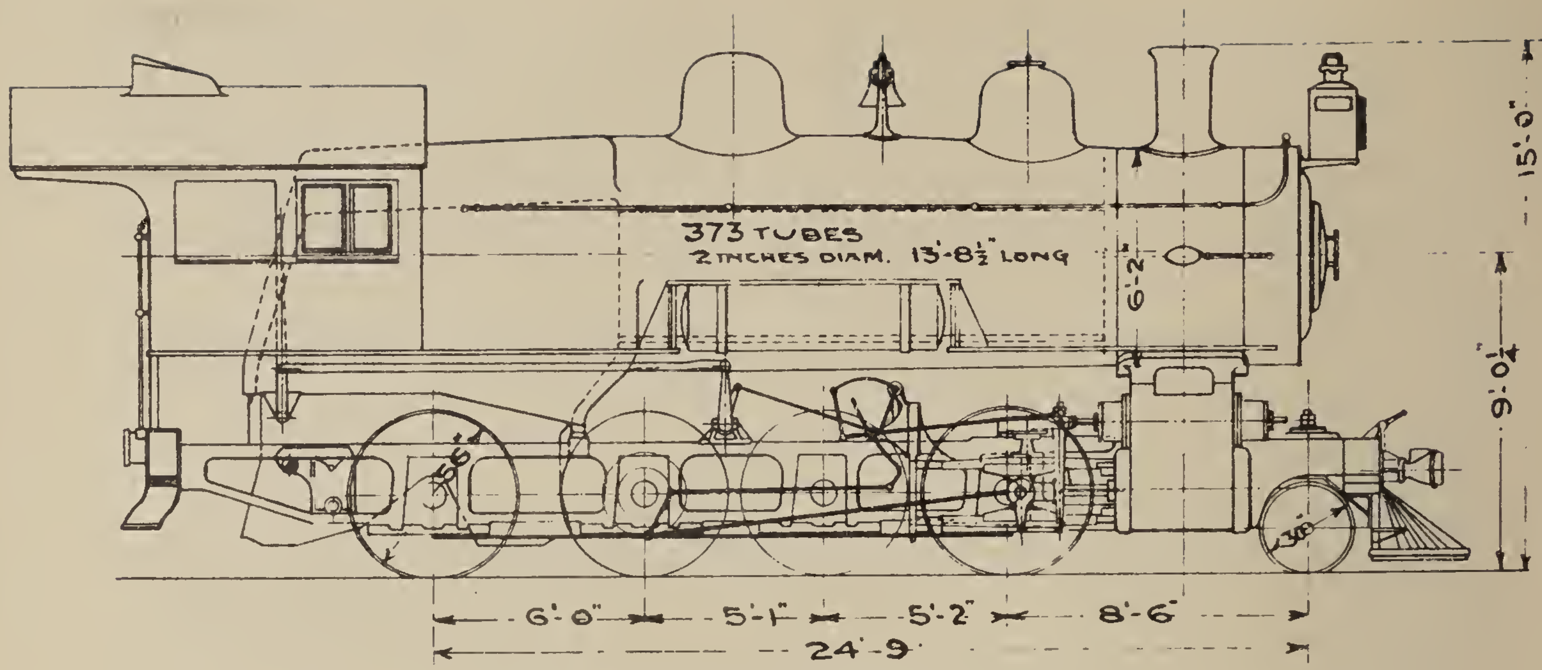
35. The Stayman valve is very wasteful in the consumption of steam and coal and should not be used in any service (Paragraphs 22 and 25).

36. There is pending a complete series of trials to show the leakage of piston valves of sizes ranging from 12 to 18 inches in diameter with various designs of rings. These are to be made on a specially constructed machine. We believe, therefore, in view of the equal performance and of the advantage in maintenance cost of the "L" ring type (Paragraphs 32 and 33) that it should be used for new work and for renewal of American valves when the spool requires replacement.

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
Genl. Supt. Motive Power.

TEST DEPARTMENT,
ALTOONA, PENNA.,
April 23, 1912.



CLASS H6b LOCOMOTIVE.
The Locomotive used in the Tests.
Fig. 1.

THE LEADING DIMENSIONS OF THE "H6b" LOCOMOTIVE ARE AS FOLLOWS:

Total weight, pounds	198,267
Weight on drivers, pounds	176,600
Cylinders (simple), inches	22x28
Diameter of drivers, inches	56
Fire-box heating surface, square feet	166.4
Heating surface in tubes (water side), square feet	2673.68
Total heating surface (based on water side of tubes), square feet	2839.74
Total heating surface (based on fire side of tubes), square feet	2505.29
Grate area, square feet	48.66
Boiler pressure, pounds	205
Valves	American, Stayman and "L" type
Valve motion	Walschaerts
Fire-box, type	Belpaire
Number of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.28

The maximum tractive effort is 39,773 pounds, which is calculated on the assumption that 80 per cent. of the boiler pressure (205 pounds) is available as mean effective pressure at starting.

"L" TYPE VALVE.
Assembled.

AMERICAN VALVE.
Assembled.

STAYMAN VALVE.
Assembled.
12 inch valve.

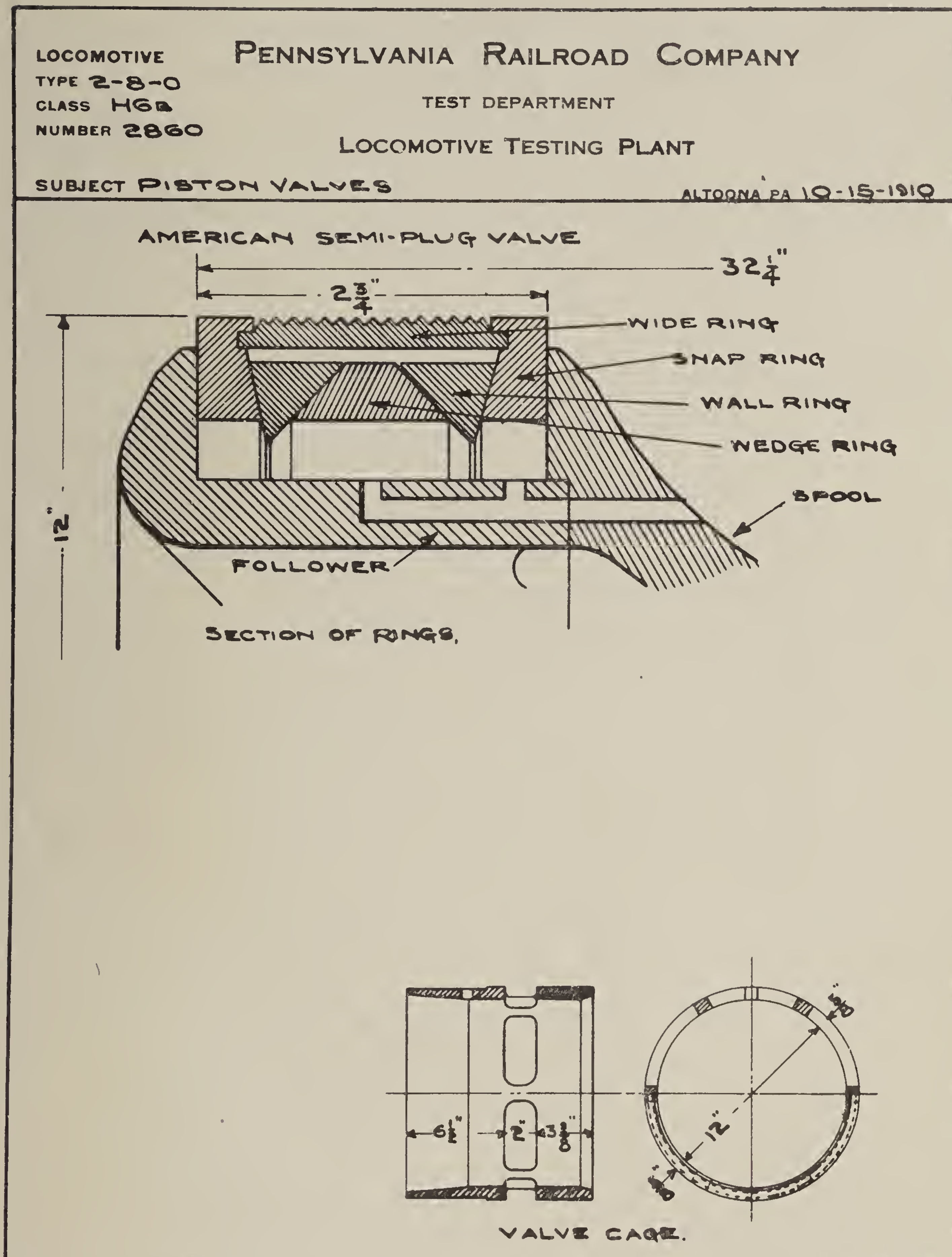
Fig. 2.

AMERICAN VALVE.
Partly Dismantled.
This is a 14 inch valve of the same general design of the 12 inch valve tested.

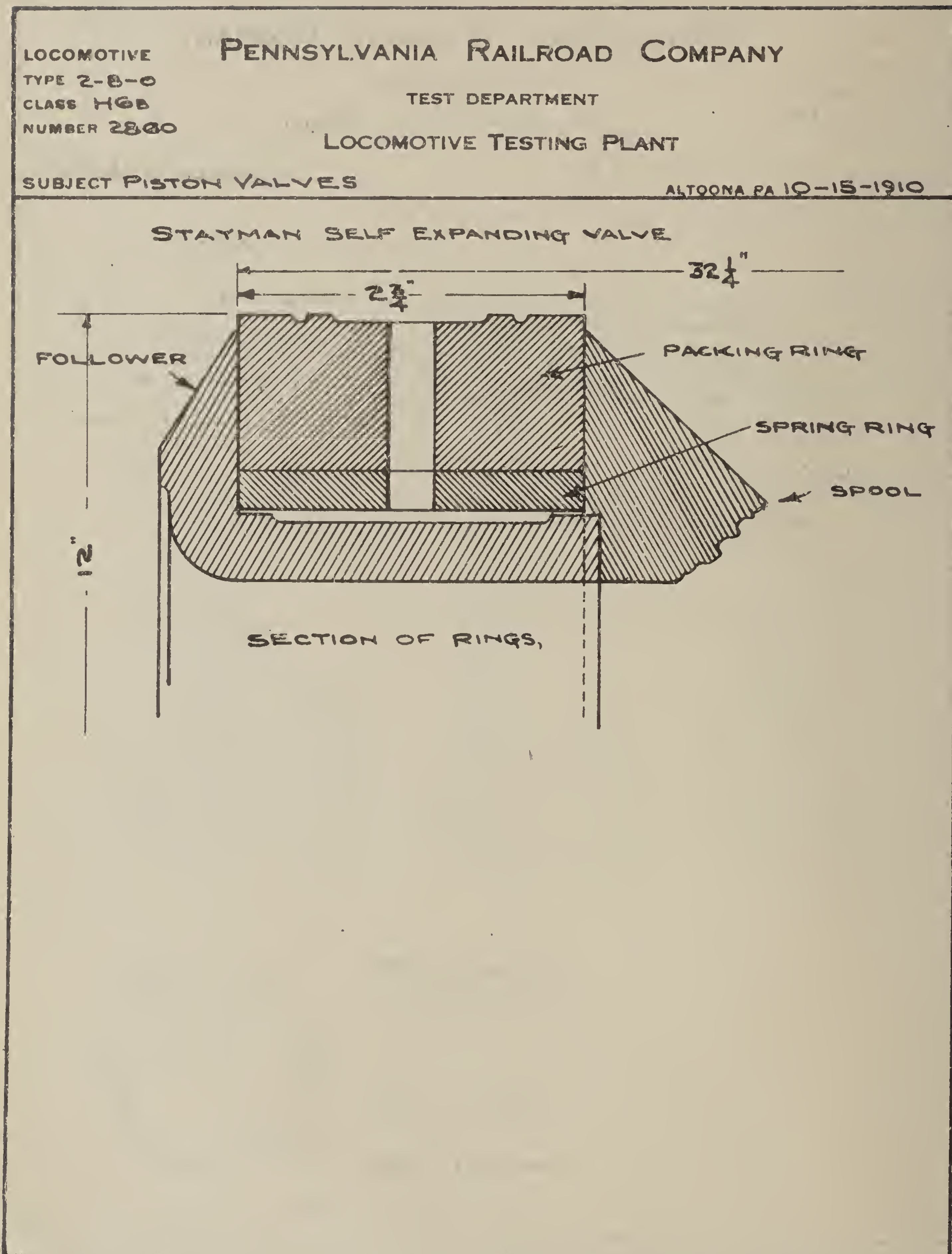
STAYMAN VALVE.
Partly Dismantled.
12 inch valve.

"L" TYPE VALVE.
Partly Dismantled.

Fig. 3.

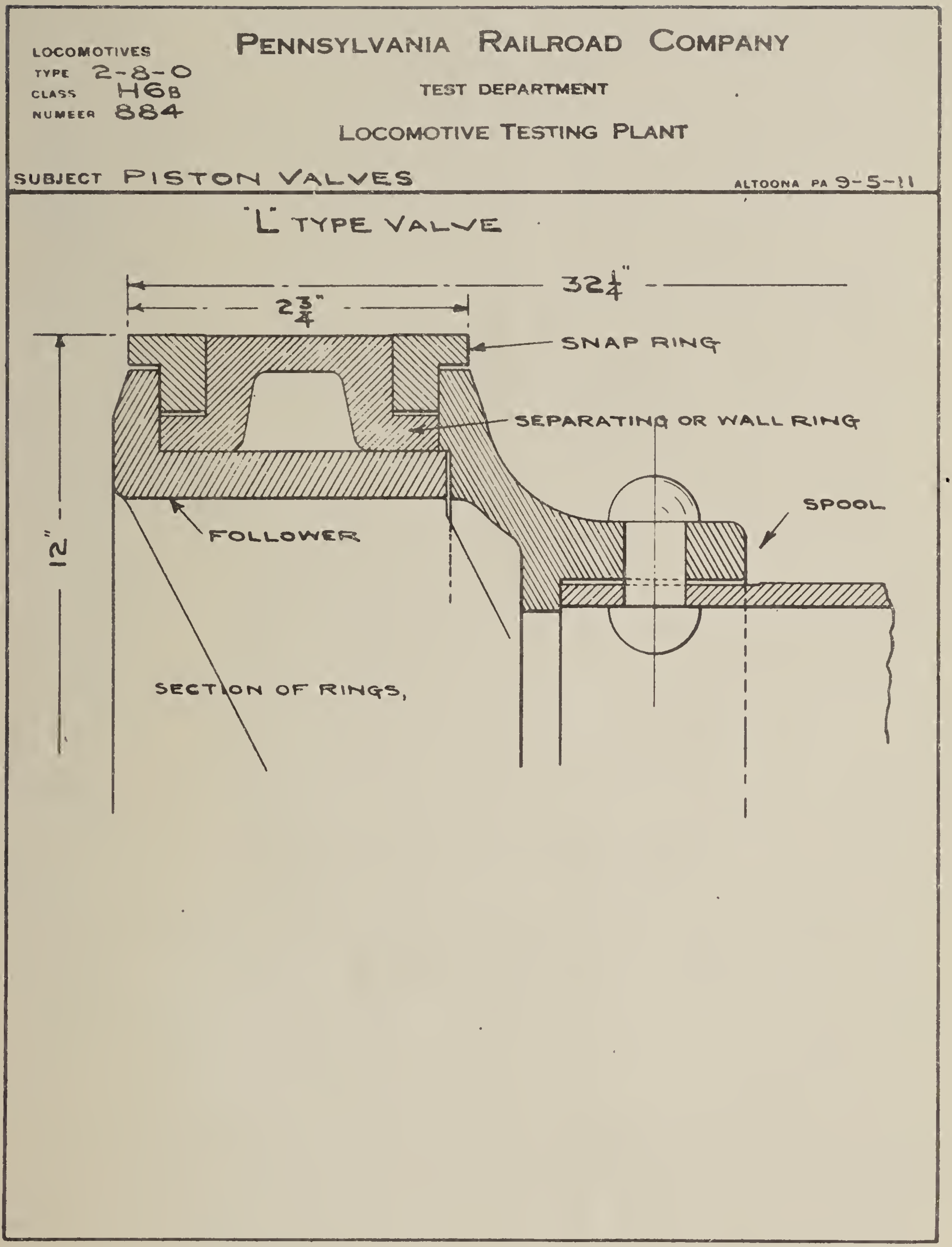


THE AMERICAN SEMI-PLUG PISTON VALVE, SECTION THROUGH THE PACKING RINGS.
There are two packing rings with a wide ring between. Under the wide ring are three wedge rings.
The lower drawing shows the cast-iron cage that is pressed into each end of the steam chest.
Fig. 4.

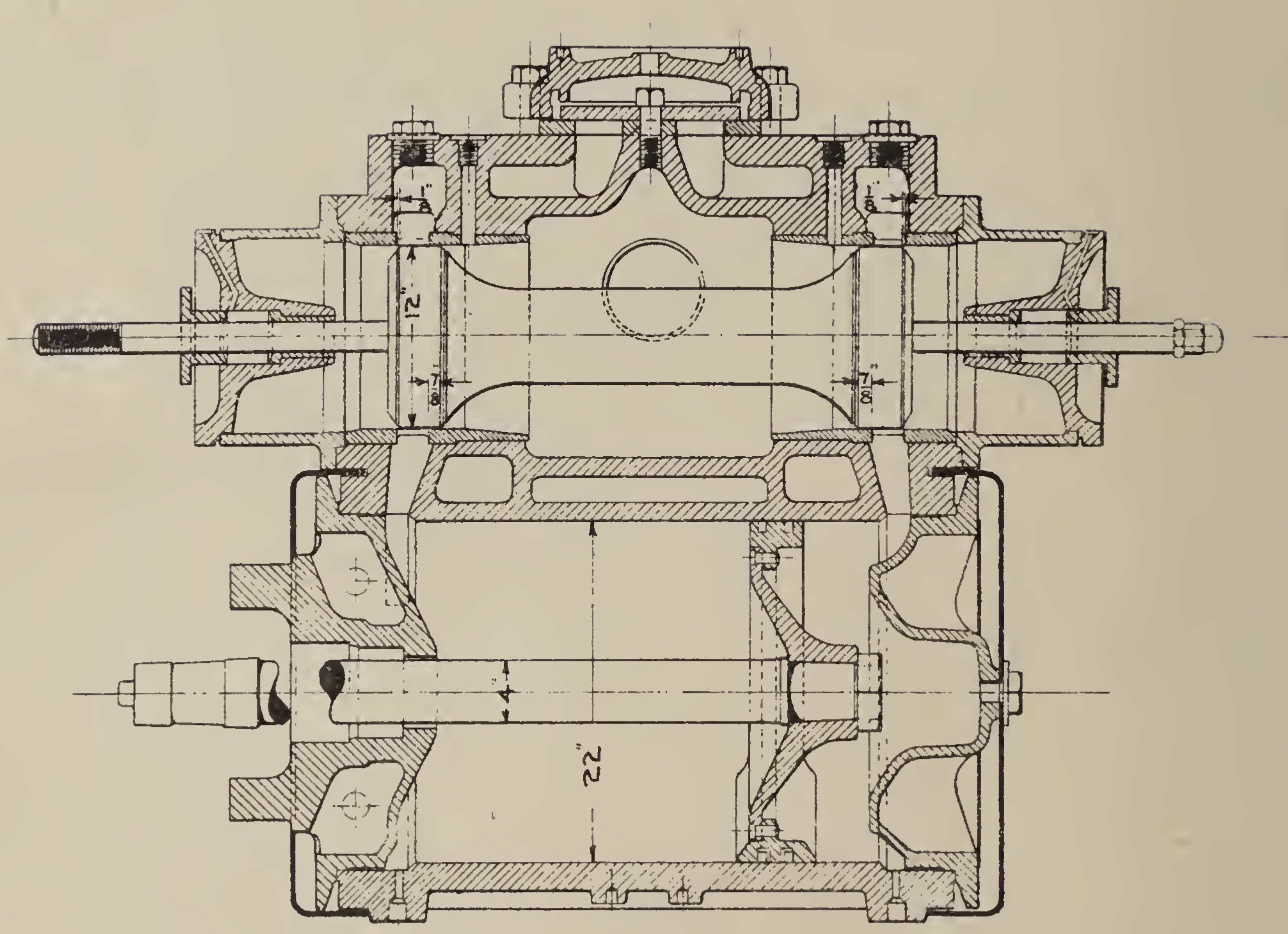


THE STAYMAN SELF-EXPANDING PISTON VALVE, SECTION THROUGH PACKING RINGS. The packing ring is 1¼ inches thick and 2¾ inches wide. The thin ring under it is the steel expansion or spring ring.

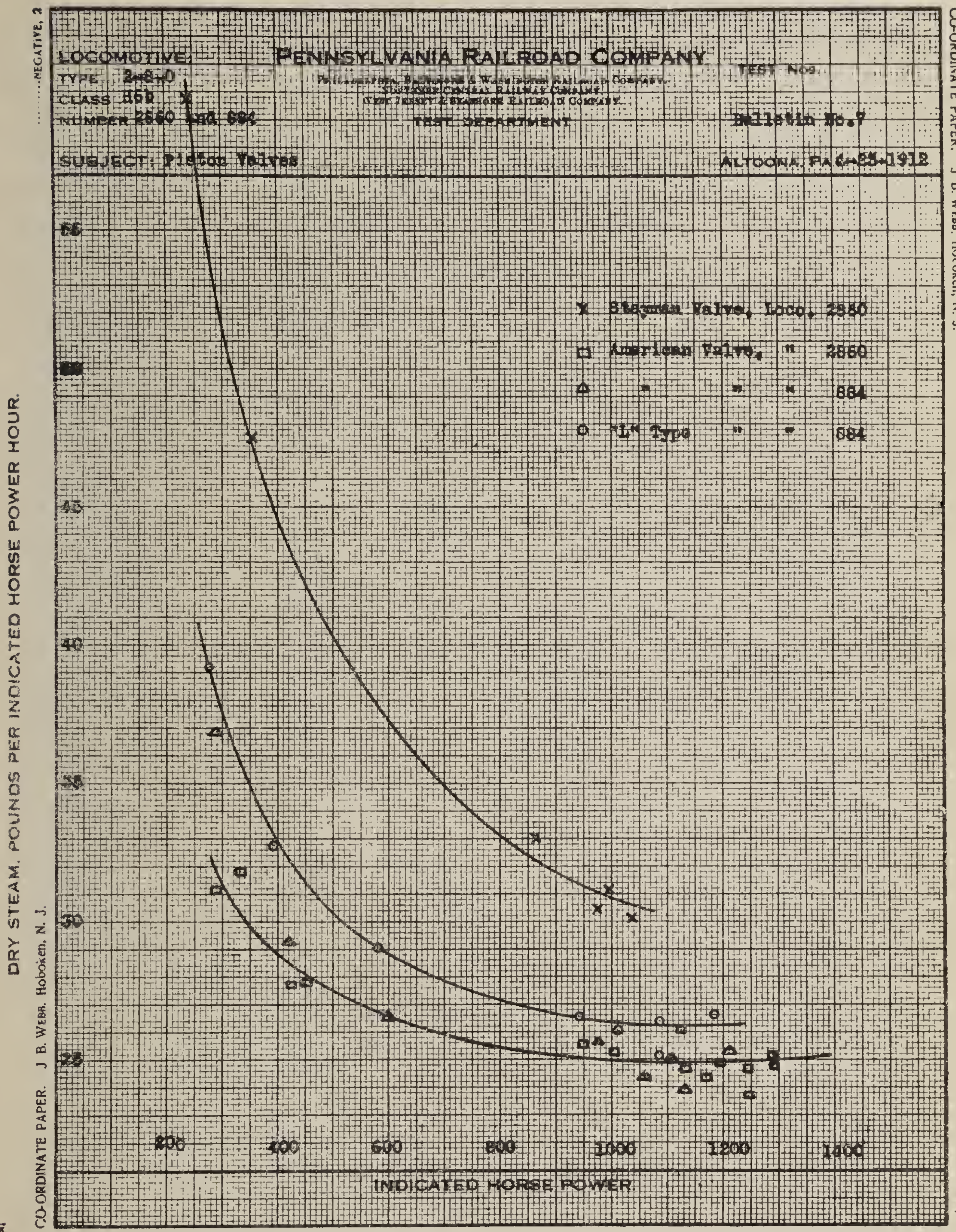
Fig. 5.



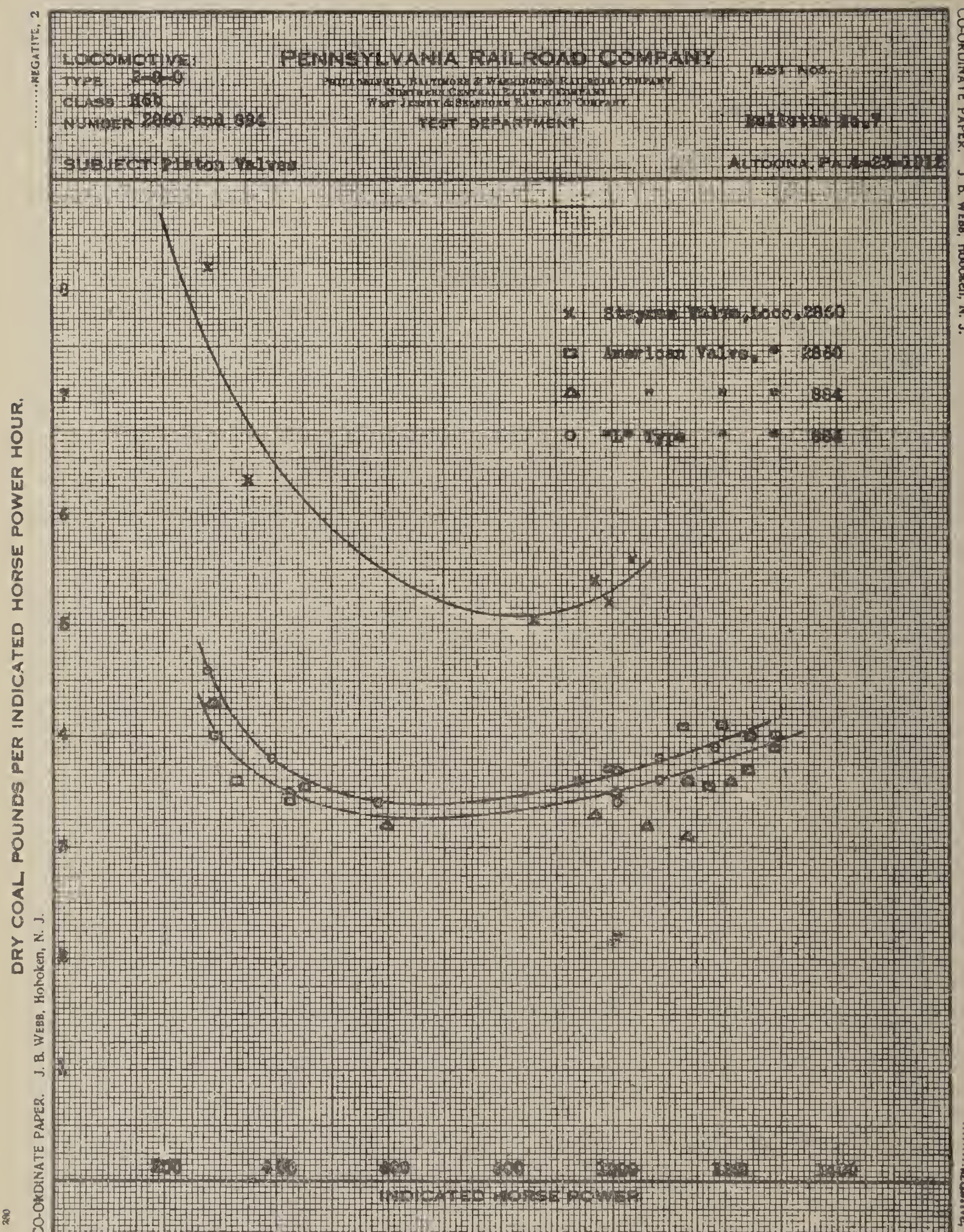
THE "L" TYPE VALVE, SECTION THROUGH RINGS.
The two packing rings are "L" shape in section.
Fig. 6.



SECTION THROUGH CYLINDER AND PISTON VALVE, H6b CLASS LOCOMOTIVE.
The valve has inside admission. The steam lap is $\frac{7}{8}$ inch negative. The exhaust lap is $\frac{1}{8}$ inch negative. Above the valve there is a flat by-pass or drifting valve.
Fig. 7.



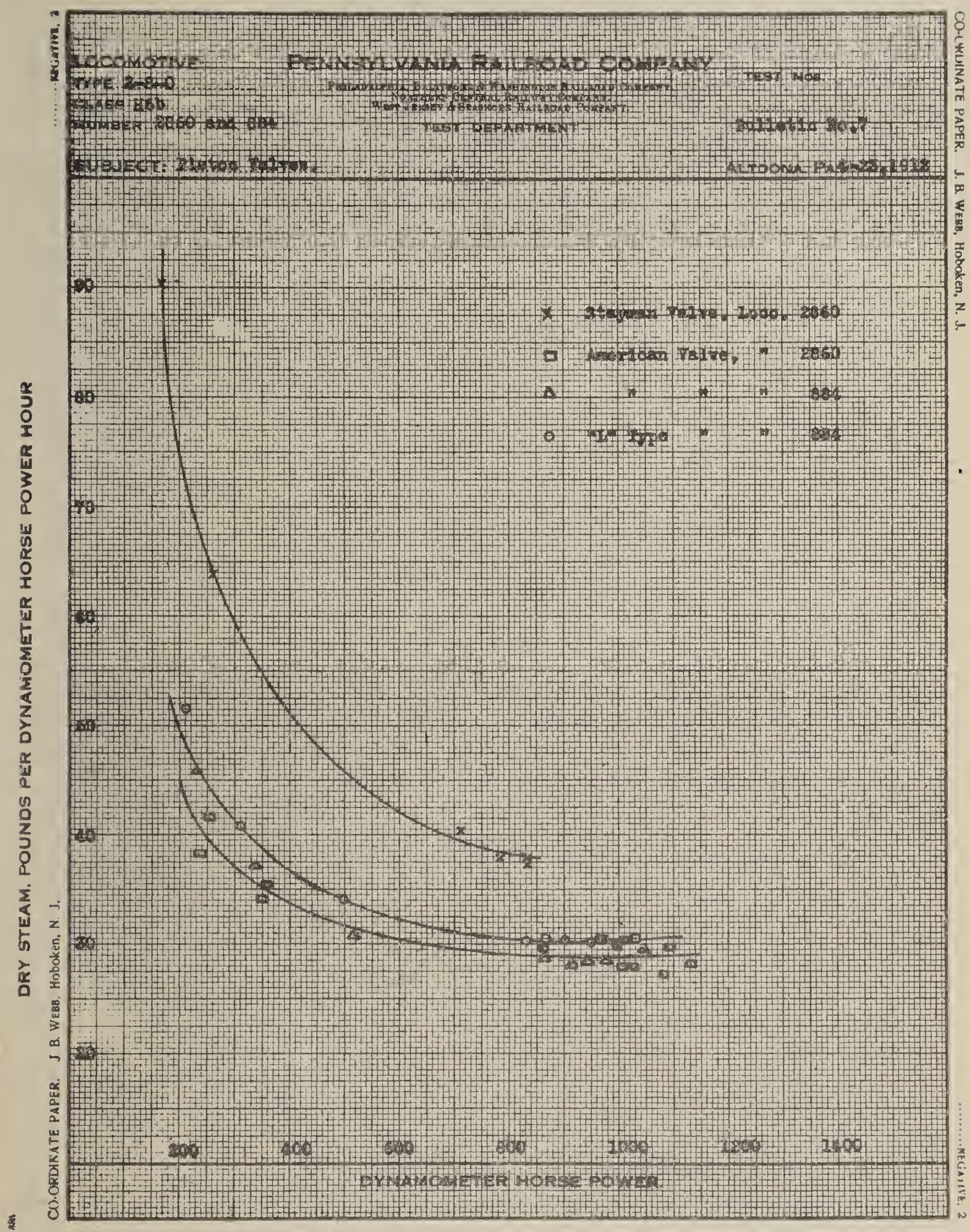
INDICATED HORSEPOWER AND STEAM PER HORSEPOWER FOR THE THREE VALVES.
The Stayman valve shows excessive leakage of steam. The "L" type shows a higher water rate than the American valve.
Fig. 8.



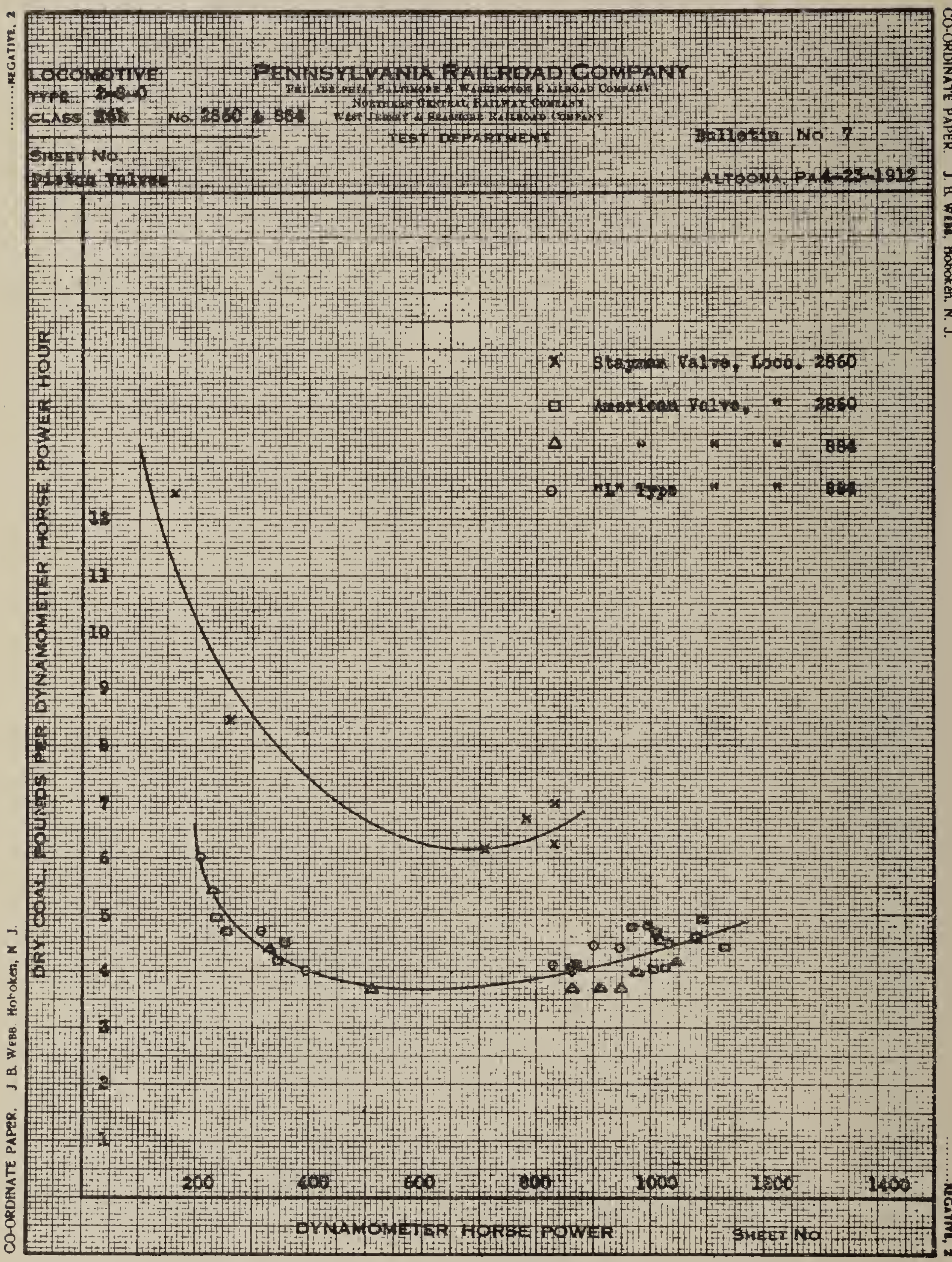
INDICATED HORSEPOWER AND COAL PER HORSEPOWER.

The Stayman valve uses very much more coal than the others per unit of power. The "L" type and American show results practically equal.

Fig. 9.



DYNAMOMETER OR DRAWBAR HORSEPOWER AND STEAM.
The valves show the same characteristics as in Fig. 7.
Fig. 10.



DYNAMOMETER HORSEPOWER AND COAL.

This diagram shows the net power per pound of coal. The Stayman valve uses from 6 to 12.5 pounds per unit of power, while the "L" type and American use from 3.5 to 6 pounds and no difference can be found between them.

Fig. 11.

M. P. 894 A—Slab Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company.
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: JAMISON COAL

SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG ALTOONA, PA., 10-15-1910

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	CONDITION OF VALVES AND CAGES	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	198	199	203	268 to 271		217	222	225	248	238
1200.524	40-20-F	3	6.64	FULL	18.8	OLD	203.8	1.1	0	14186	5
1200.525	60-20-F	3	9.97	"	18.1	"	203.9	1.6	0	"	34
1200.526	80-40-F	2	13.29	"	39.6	"	203.4	42	.1	"	53
1200.527	100-40-F	2	16.61	"	40.6	"	204.9	5.1	.1	"	36
1200.528	120-40-F	2	19.94	"	42.1	"	204.4	6.2	.1	"	157
1200.529	140-30-F	2	23.26	"	34.7	"	204.6	5.0	.1	"	76
1200.530	160-30-F	1	26.58	"	32.8	"	204.9	5.4	.1	"	149

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.524	1163	23.90	9640	11405	4.55	9.81	330.6	66.79			
1200.525	1452	29.84	11900	14079	5.62	9.70	408.1	66.04			
1200.526	3505	72.03	24669	29340	11.71	8.37	850.4	56.98			
1200.527	4086	83.97	28391	33825	13.50	8.28	980.4	56.37			
1200.528	5004	102.84	32384	38589	15.40	7.71	1118.5	52.49			
1200.529	4148	85.25	28833	34362	13.72	8.28	996.0	56.37			
1200.530	4964	102.02	29770	35477	14.16	7.15	1028.3	48.68			

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.524	9014	289.4	4.02	31.15		13273	235.2	4.94	38.32	81.3	3.6	
1200.525	11756	423.7	3.43	27.75		13026	346.2	4.19	33.96	81.7	4.3	
1200.526	24215	947.4	3.70	25.56		24358	863.2	4.06	28.05	91.1	4.4	
1200.527	28047	1133.2	3.61	24.75		22669	1004.2	4.07	27.93	88.6	4.4	
1200.528	31942	1288.3	3.88	24.79		21303	1132.5	4.42	28.20	87.9	4.1	
1200.529	28504	1170.3	3.54	24.36		16489	1022.6	4.06	27.87	87.4	4.4	
1200.530	29410	1244.2	3.99	23.64		15269	1082.3	4.59	27.17	87.0	3.9	

RESULTS OF TESTS WITH AMERICAN VALVES, OLD VALVES AND CAGES.
Table 1.

M. P. 304 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL: JAMISON COAL

SUBJECT: PISTON VALVES, STAYMAN

ALTOONA, PA., 10-15-1910

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	CONDITION OF VALVES AND CAGES	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.556	40-20-F.	3	6.62	FULL	18.7	NEW	204.5	2.2	0	13547	26
1200.557	60-20-F	3	9.93	"	19.1	"	203.6	2.4	0	-	27
1200.554	80-40-F	2	13.24	"	37.5	"	202.6	5.4	.1	-	112
1200.555	100-40-F	2	16.55	"	39.0	"	201.6	6.4	.1	-	193
1200.558	140-30-F	1.25	23.16	"	30.0	"	202.9	5.9	.1	-	277
1200.559	160-30-F	1	26.47	"	28.4	"	202.1	5.9	.1	-	428

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.556	2002	41.14	15796	18777	7.50	9.38	544.3	66.87			
1200.557	2212	45.48	17433	20704	8.26	9.36	600.1	66.73			
1200.554	4384	90.10	28993	34617	13.82	7.90	1003.4	56.32			
1200.555	5186	106.58	31936	38116	15.21	7.35	1104.8	52.40			
1200.558	5239	107.67	30288	36188	14.44	6.91	1048.9	49.26			
1200.559	5781	118.81	31804	37982	15.16	6.57	1100.9	46.84			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1200.556	14566	243.4	8.23	59.84		9114	160.8	12.45	90.58	66.1	1.51	
1200.557	16694	351.4	6.30	47.51		9863	261.1	8.47	63.94	74.3	2.28	
1200.554	28478	862.6	5.04	33.01		20084	708.9	6.18	40.17	81.2	3.04	
1200.555	31152	995.8	5.21	31.28		18852	831.8	6.23	37.45	83.5	3.02	
1200.558	29668	971.1	5.39	30.55		12670	782.6	6.68	37.91	80.6	2.81	
1200.559	31238	1036.8	5.58	30.14		11758	830.0	6.97	37.64	80.1	2.70	

RESULTS OF TESTS WITH STAYMAN VALVES, NEW VALVES AND CAGES.
Table 2.

M. P. 394 A—Sixth Sheet
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL: JAMISON COAL

SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG   ALTOONA, PA., 10-15-1910

	Running Conditions						Boiler Performance				
Test Number	Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Condition of Valves and Cages	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	226	248	238
1200.571	40-20-F.	3	6.62	FULL	22.5	NEW	205.2	1.3	0	13766	42
1200.572	60-20-F	3	9.93	"	21.2	"	204.9	1.6	0	"	23
1200.573	80-40-F	2	13.24	"	40.9	"	204.8	4.4	.1	"	59
1200.574	100-40-F	2	16.55	"	42.3	"	201.2	5.4	.1	"	181
1200.575	120-40-F	1.5	19.85	"	41.7	"	203.9	6.2	.1	"	147
1200.576	140-30-F	2	23.16	"	35.5	"	202.5	5.4	0	"	172
1200.577	160-30-F	1	26.47	"	32.1	"	205.0	5.7	.1	"	193

	Boiler Performance								Engine Performance	
				Equivalent Evaporation from and at 212° F., Pounds						
Test Number	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350	220	230
1200.571	1188	24.41	10966	13008	5.19	10.95	377.0	76.82		
1200.572	1597	32.82	13213	15679	6.26	9.82	454.5	68.90		
1200.573	3536	72.67	25738	30779	12.29	8.70	892.2	61.04		
1200.574	4612	94.78	29875	35662	14.23	7.73	1034.0	54.23		
1200.575	5359	110.13	32875	39287	15.68	7.33	1138.8	51.43		
1200.576	4791	98.46	30150	36064	14.40	7.53	1045.4	52.83		
1200.577	4623	95.01	31154	37240	14.86	8.06	1079.4	56.55		

	Engine Performance				Locomotive Performance					
Test Number	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)
	214	379	380	381	265	383	384	385	398	399
1200.571	10491	329.5	3.61	31.84	14302	262.4	4.71	41.56	76.6	3.93
1200.572	12524	450.1	3.55	27.82	13392	354.5	4.50	35.33	78.8	4.11
1200.573	25343	1003.4	3.52	25.26	24385	860.5	4.11	29.45	85.8	4.50
1200.574	29323	1126.5	4.09	26.03	21898	966.1	4.77	30.35	85.8	3.88
1200.575	32477	1289.3	4.16	25.19	20642	1092.9	4.90	29.72	84.8	3.77
1200.576	29651	1195.0	4.01	24.81	16106	994.8	4.82	29.81	83.2	3.84
1200.577	30568	1242.2	3.72	24.61	14342	1012.4	4.57	30.19	81.5	4.05

RESULTS OF TESTS WITH AMERICAN VALVES, NEW VALVES AND CAGES.
Table 3.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 884

FUEL: JAMISON COAL

Average Results of Locomotive Tests

SUBJECT: PISTON VALVES, "L" TYPE

ALTOONA, PA., 10-18-1911

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	S. P. M. Cut-off Throttle	196	199	203	268 to 271	217	222	226	248	238
2201	40-20-F	3	6.6	FULL	18.2	206.4	1.1	0	14023	5
2202	60-20-F	3	9.9	"	18.2	206.0	1.4	0	"	7
2203	60-30-F	2.5	9.9	"	28.9	206.8	2.2	0	"	17
2204	80-40-F	2	13.2	"	39.2	205.5	4.3	0	"	37
2205	100-40-F	2	16.5	"	41.1	204.8	5.2	0	"	48
2206	120-40-F	2	19.8	"	40.9	205.8	6.0	0	"	114
2207	140-30-F	2	23.1	"	30.5	206.0	4.8	0	"	57
2208	160-30-F	2	26.4	"	30.0	205.6	4.9	0	"	62

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350	220	230
2201	1284	25.6	11520	13679	5.4	10.7	396.5	73.7		
2202	1496	29.8	12972	15389	6.1	10.3	446.1	71.2		
2203	1966	39.1	17195	20558	8.2	10.5	595.9	72.3		
2204	3387	67.4	25011	30091	12.0	8.9	872.2	61.4		
2205	4152	82.7	28792	34504	13.7	8.3	1000.1	57.5		
2206	4653	92.6	31628	37954	15.1	8.2	1100.1	56.4		
2207	3467	69.0	26373	31703	12.6	9.1	918.9	63.2		
2208	3931	78.3	27379	32994	13.1	8.4	956.4	58.0		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds
	214	379	380	381
2201	10958	279.2	4.6	39.3
2202	12873	394.3	3.8	32.7
2203	16904	581.0	3.4	29.1
2204	24990	943.9	3.6	26.5
2205	28716	1086.5	3.8	26.4
2206	31583	1185.4	3.9	26.6
2207	26301	1012.7	3.4	26.0
2208	27332	1086.0	3.6	25.2

TEST NUMBER	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)
	285	383	384	385	398	399
2201	12070	212.6	6.0	51.5	76.1	3.0
2202	11938	315.4	4.7	40.8	80.0	3.8
2203	18840	497.7	4.0	34.0	85.7	4.6
2204	23570	830.2	4.1	30.1	88.0	4.5
2205	21565	949.5	4.4	30.2	87.4	4.2
2206	19519	1031.3	4.5	30.6	87.0	4.0
2207	14005	863.3	4.0	30.5	85.2	4.5
2208	12803	901.9	4.4	30.3	83.0	4.2

RESULTS OF TESTS WITH "L" TYPE VALVES ON LOCOMOTIVE 884.
Table 4.

M. P. 884 A—Sixth Sheet
6 x 10½

11-6-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 884

FUEL: JAMISON COAL

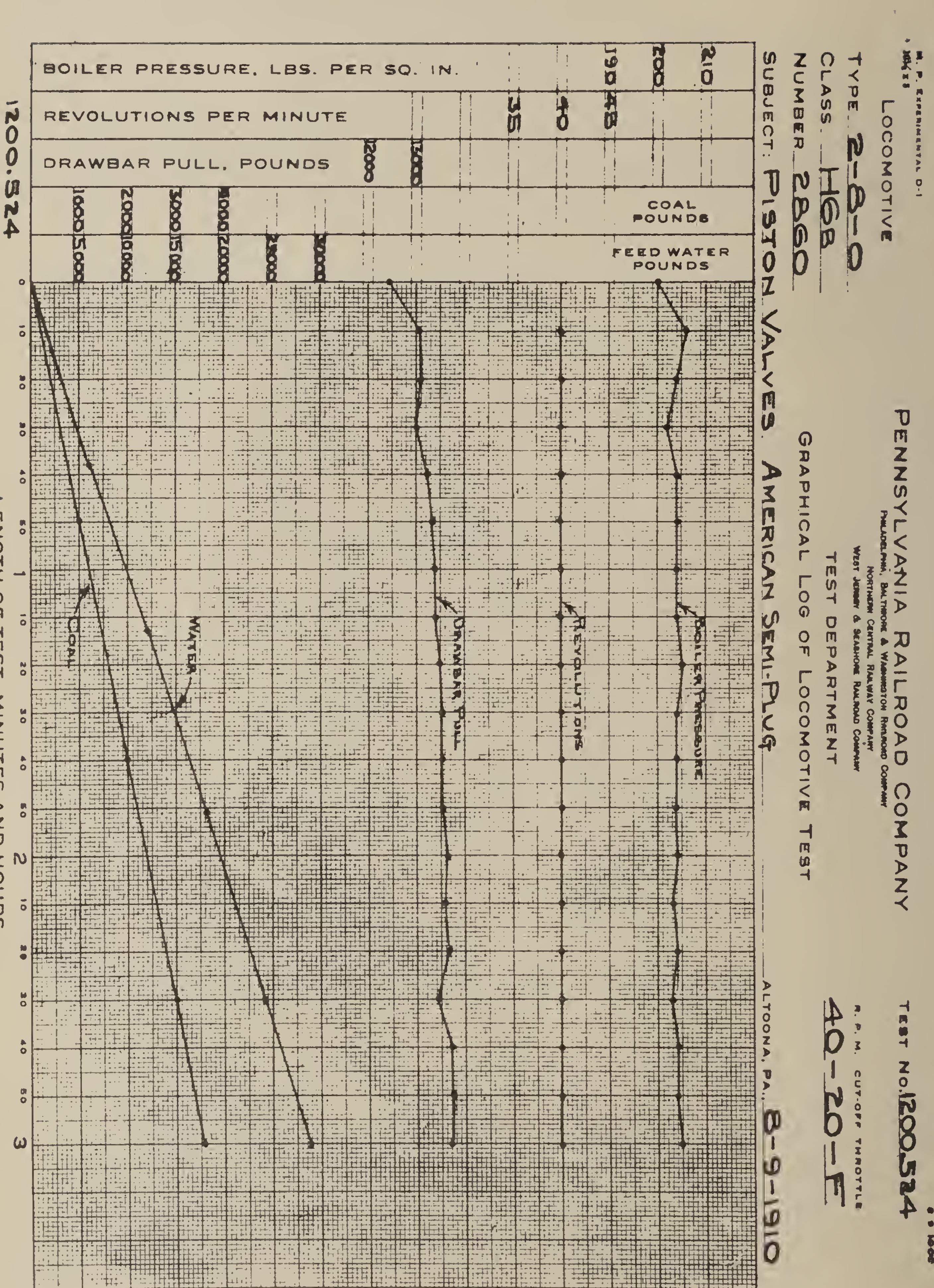
SUBJECT: PISTON VALVES, AMERICAN SEMI PLUG   ALTOONA, PA., 10-18-1911

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
2209	40-20-F	3	6.6	FULL	19.9		206.6	1.0	0	14444	7
2210	60-20-F	2.5	9.9	"	20.0		204.4	1.4	0	"	10
2211	60-30-F	2.5	9.9	"	31.0		205.9	2.2	0	"	14
2212	80-40-F	2	13.2	"	40.4		204.8	4.3	0	"	37
2213	100-40-F	2	16.5	"	41.2		204.2	5.1	0	"	32
2214	120-40-F	2	19.8	"	41.4		203.5	5.8	0	"	37
2215	140-30-F	2	23.1	"	31.2		205.8	4.2	0	"	45
2216	160-30-F	2	26.4	"	31.0		205.1	4.7	0	"	53

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
2209	1257	25.0	11314	13804	5.4	10.7	391.4	72.1			
2210	1464	29.2	12390	14702	5.9	10.0	426.2	67.4			
2211	1899	37.8	16326	19606	7.8	10.3	568.3	69.3			
2212	3188	63.5	24808	29770	11.9	9.3	862.9	62.7			
2213	3888	77.4	27994	33612	13.4	8.7	974.3	58.1			
2214	4400	87.6	30785	37074	14.8	8.4	1074.6	56.6			
2215	3384	67.4	25915	31199	12.4	9.2	904.3	61.9			
2216	3542	70.5	26984	32535	13.0	9.2	943.0	61.7			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
2209	10667	289.5	4.3	36.9		13236	233.1	5.4	45.8	80.5	3.3	
2210	12361	422.0	3.5	29.3		12693	335.3	4.4	36.9	79.5	4.0	
2211	15902	597.9	3.2	26.6		19522	515.7	3.7	30.8	86.3	4.8	
2212	24790	968.1	3.3	25.6		24493	862.7	3.7	28.7	89.1	4.8	
2213	27821	1106.6	3.5	25.1		22128	974.3	4.0	28.6	88.0	4.4	
2214	30785	1212.1	3.6	25.4		19793	1045.8	4.2	29.4	86.3	4.2	
2215	25792	1059.3	3.2	24.4		14820	913.5	3.7	28.2	86.2	4.8	
2216	26950	1128.3	3.1	23.9		13438	946.7	3.7	28.5	83.9	4.7	

RESULTS OF TESTS WITH AMERICAN VALVES ON LOCOMOTIVE 884.
Table 5.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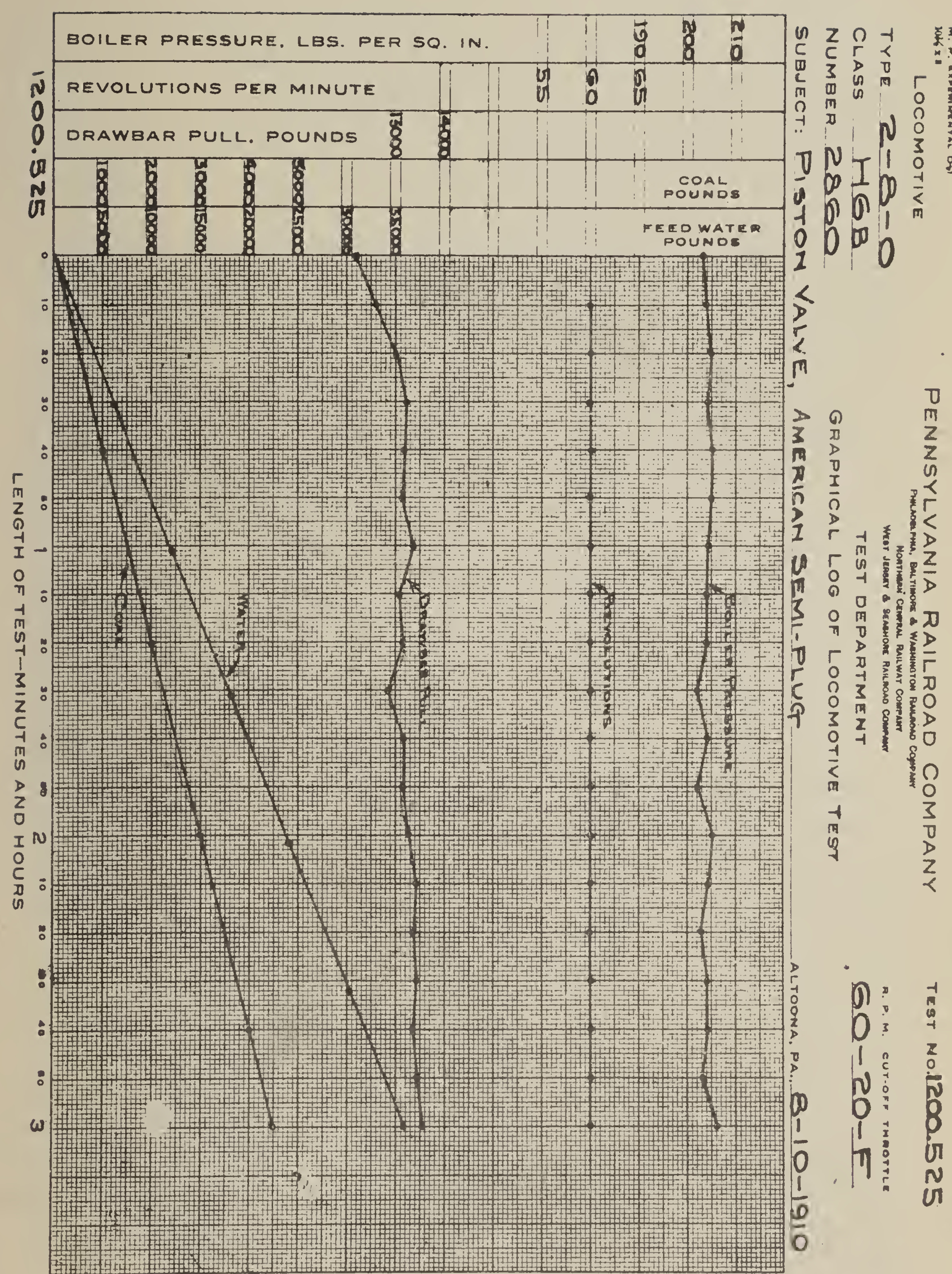
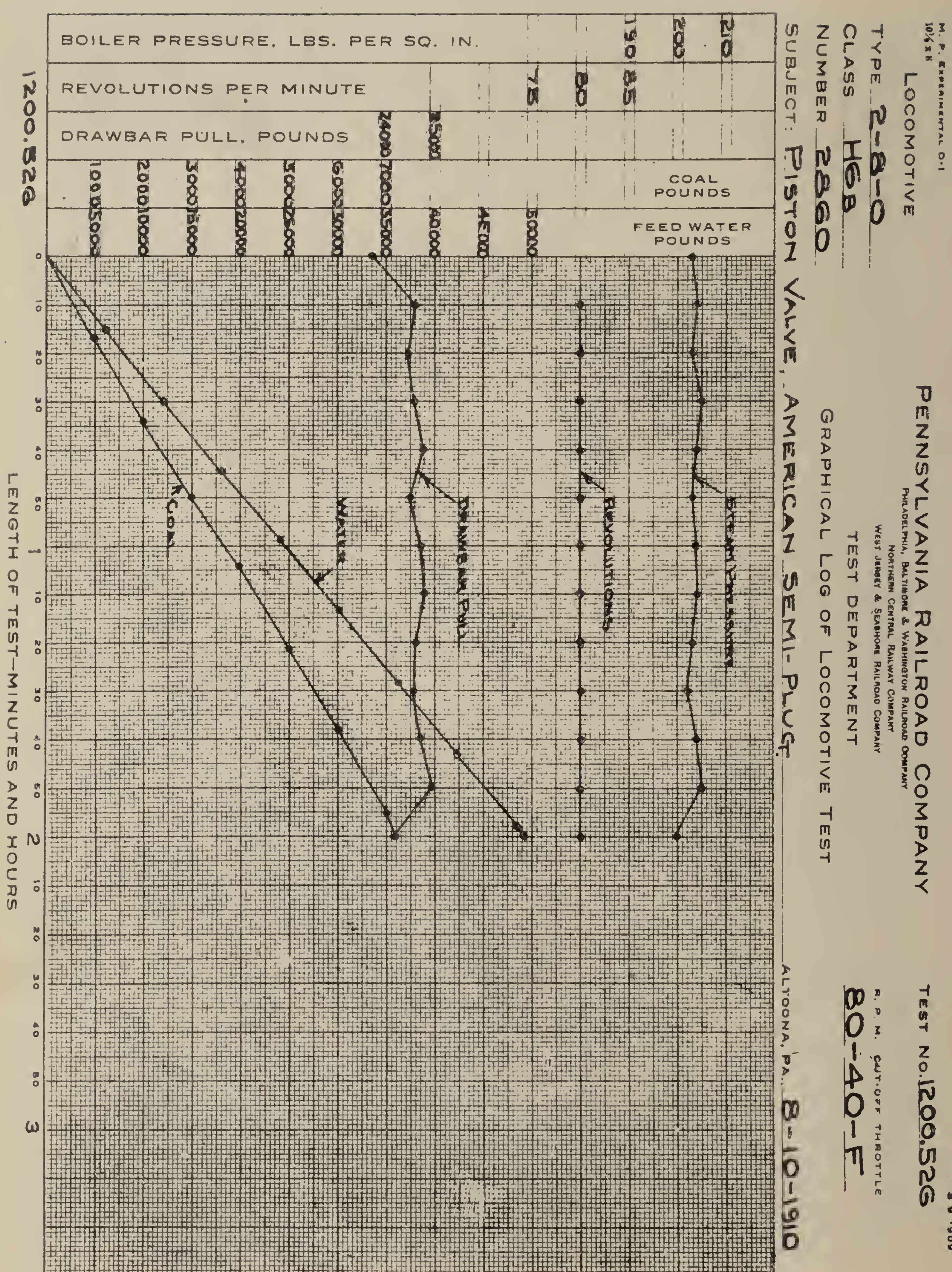
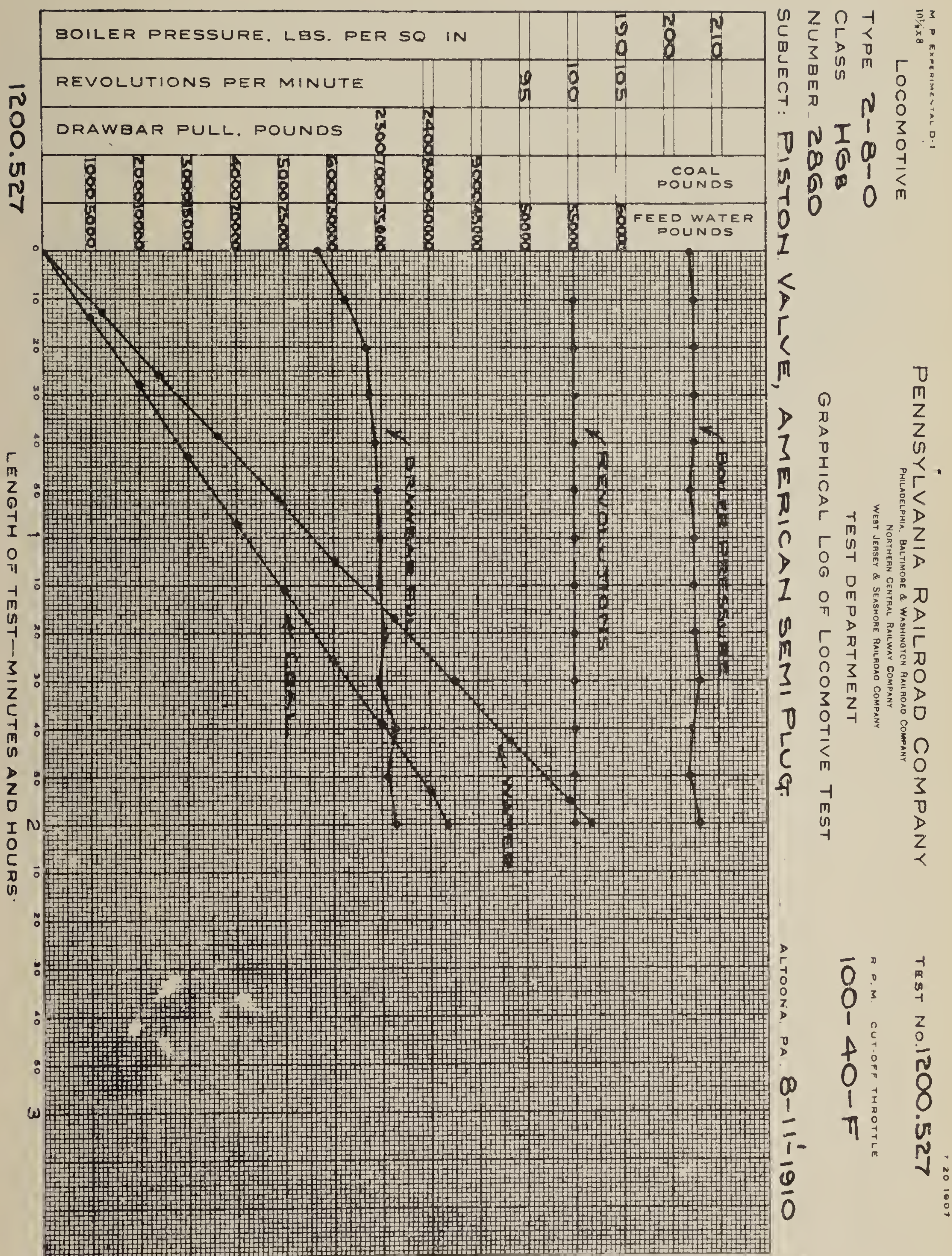
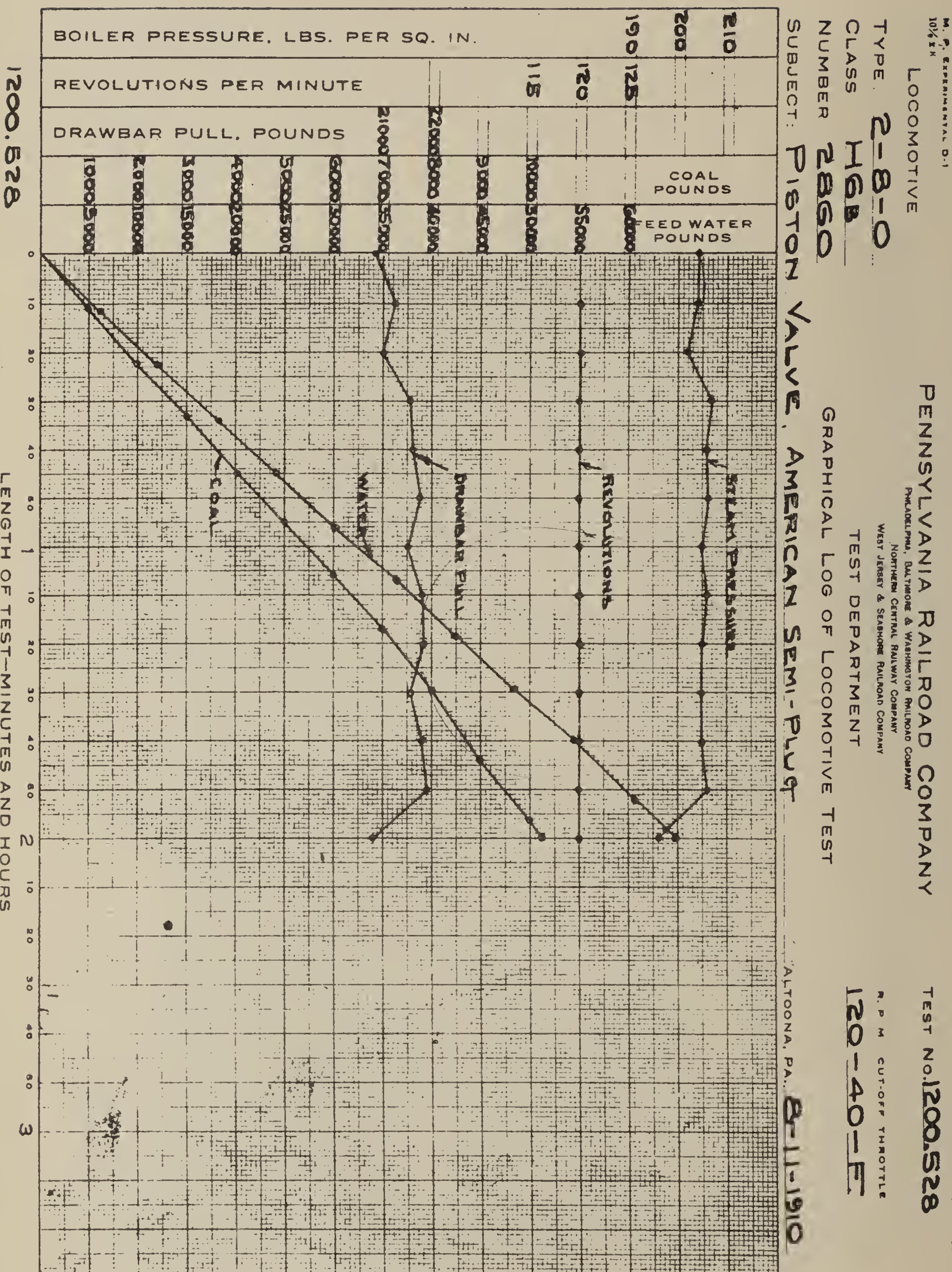
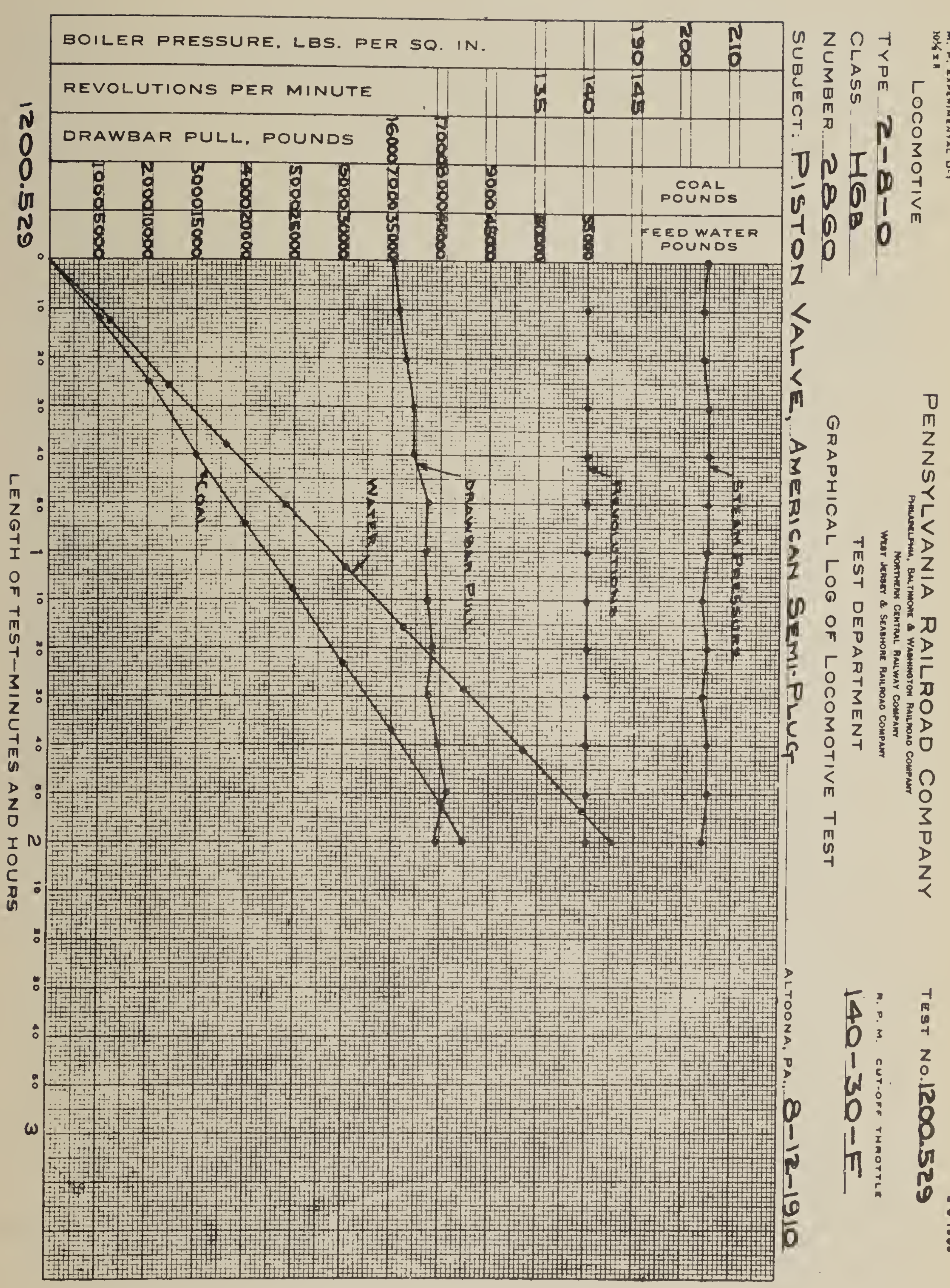
R.P.M. CUT-OFF THROTTLE
40-20-F
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES. AMERICAN SEMI-PLUG
ALTOONA, PA., 8-9-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.524

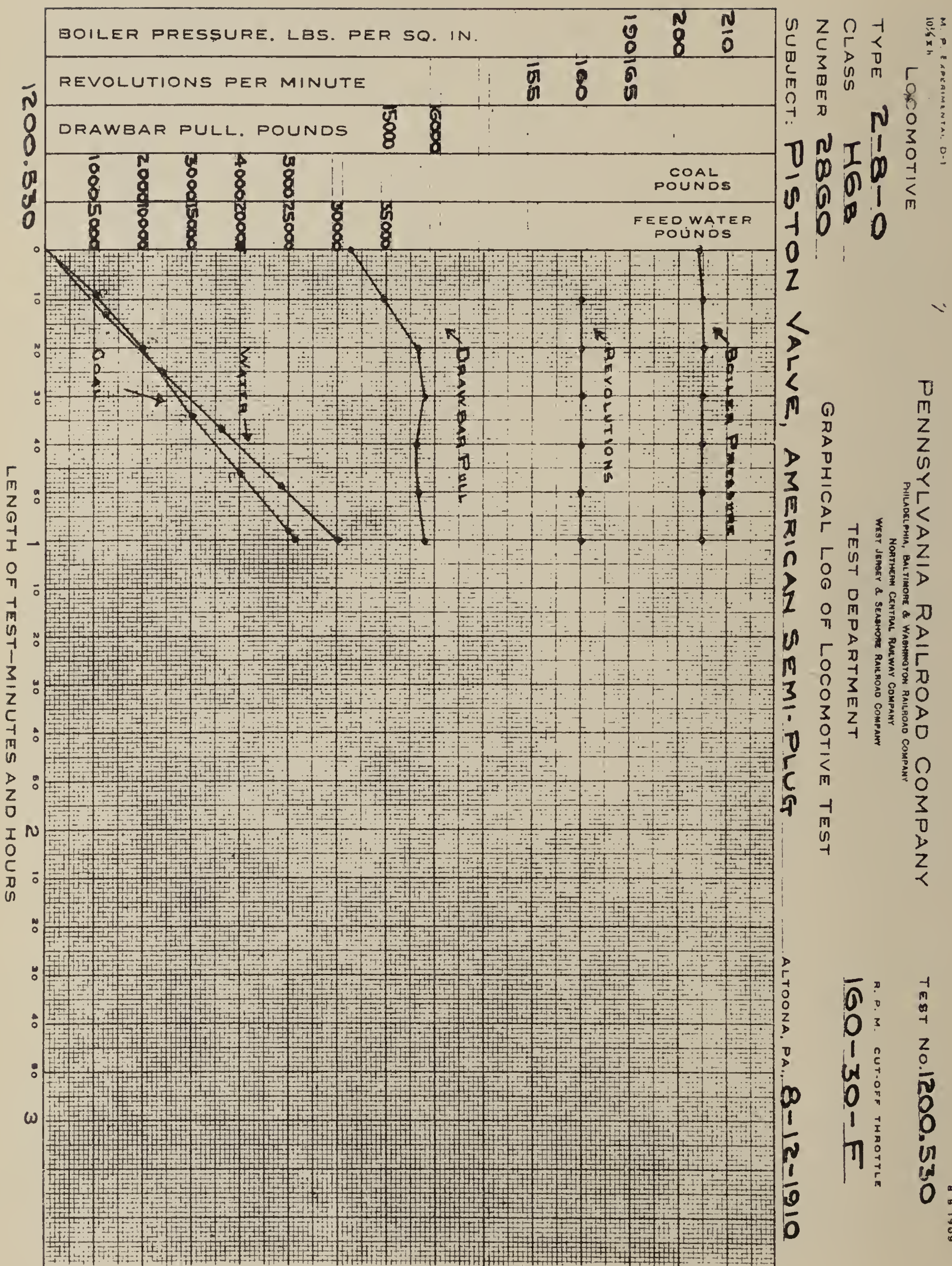

PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVE, AMERICAN SEMI-PLUG
ALTOONA, PA., 8-10-1910
TEST No. 1200.525
R. P. M. CUT-OFF THROTTLE
60-20-F
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.525

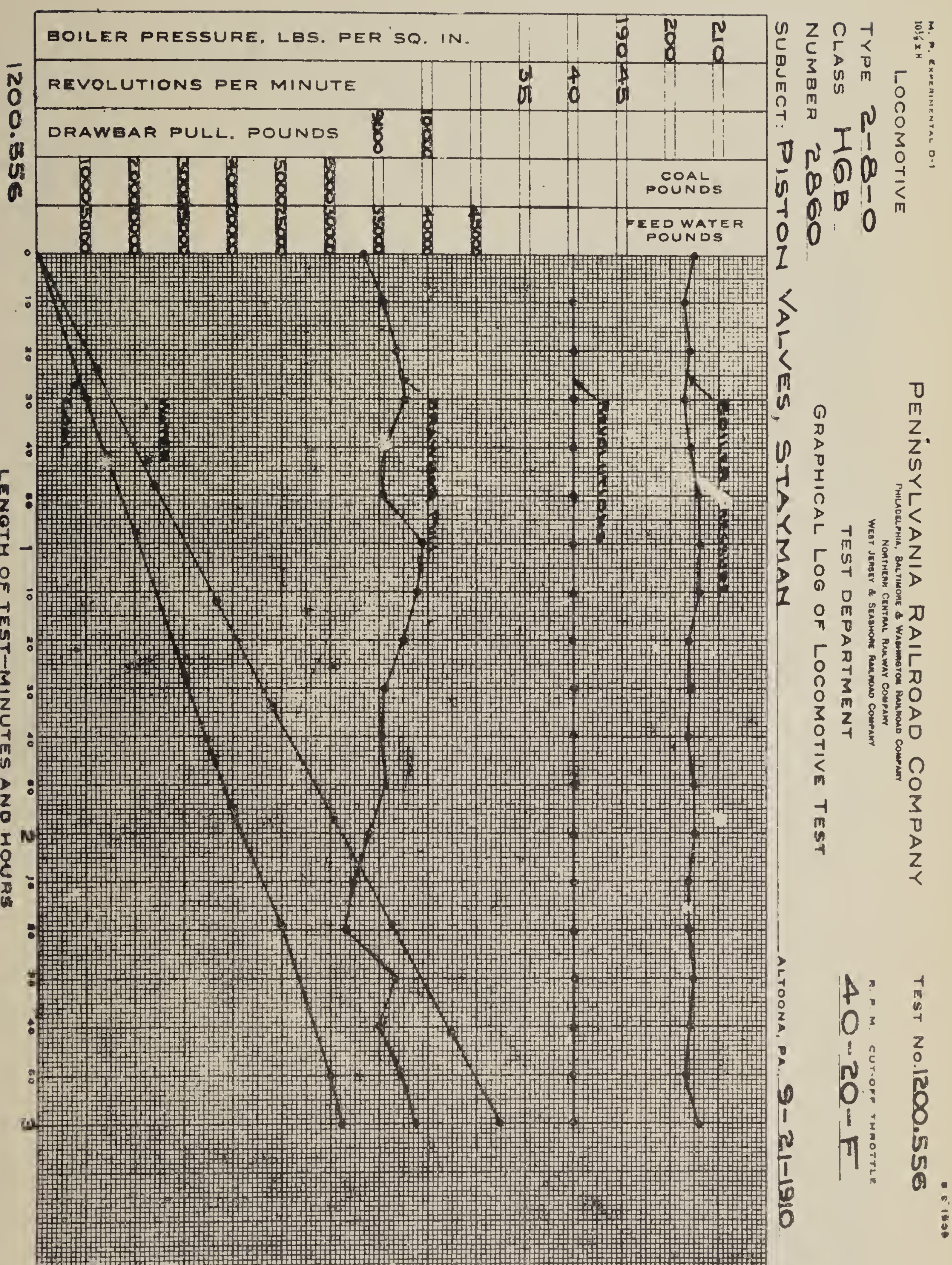

M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 2860
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Graphical Log of Locomotive Test
Test Department
Test No. 1200.52G
R. P. M. Cut-off Throttle
80-40-F
Subject: Piston Valve, American Semi-Plug
Altoona, Pa. 8-10-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
Steam Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
1200.52G

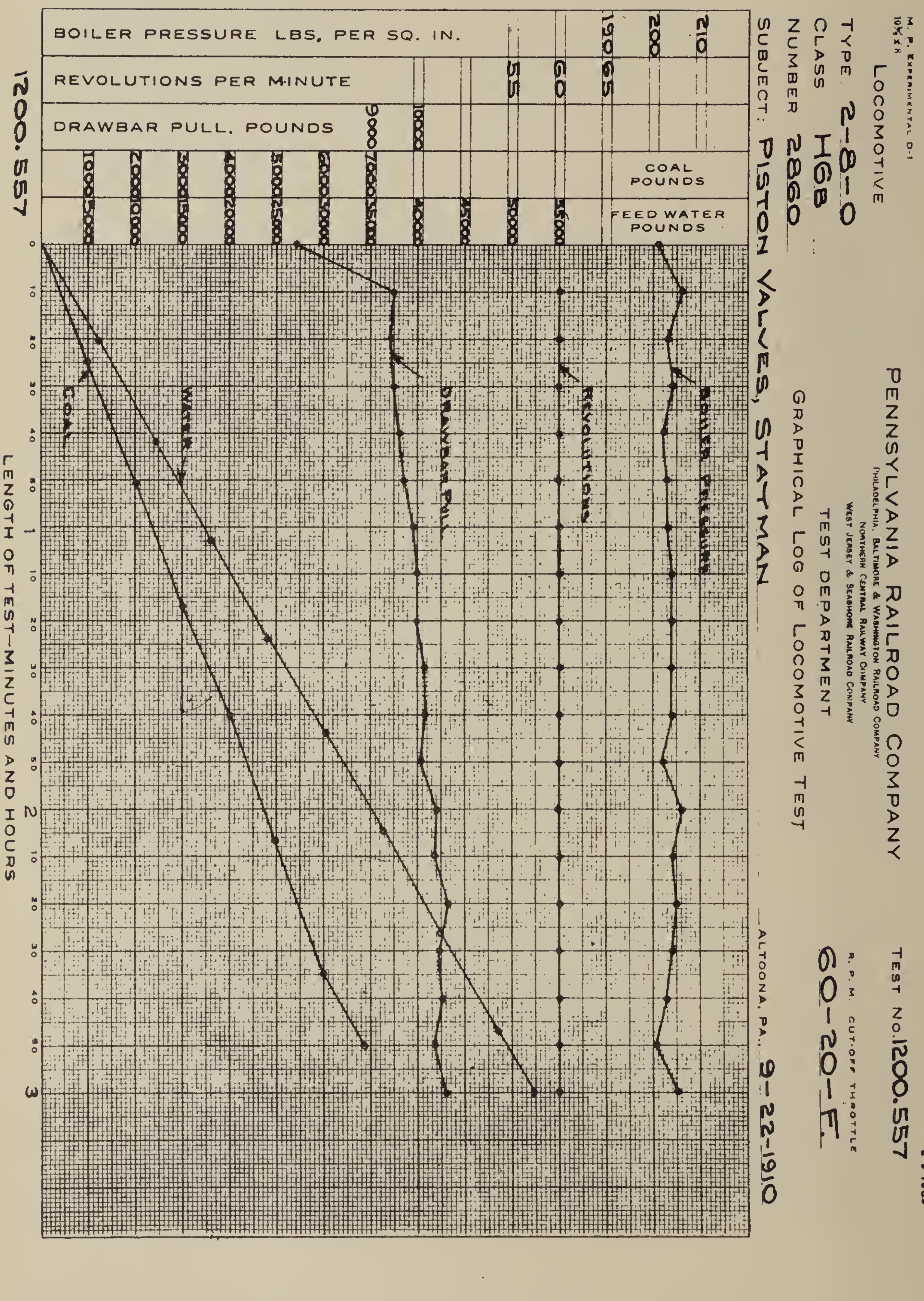

M P EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVE, AMERICAN SEMI PLUG.
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.527
R. P. M. CUT-OFF THROTTLE
100-40-F
ALTOONA, PA. 8-11-1910
BOILER PRESSURE. LBS. PER SQ IN
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
COAL
WATER
LENGTH OF TEST—MINUTES AND HOURS.
1200.527

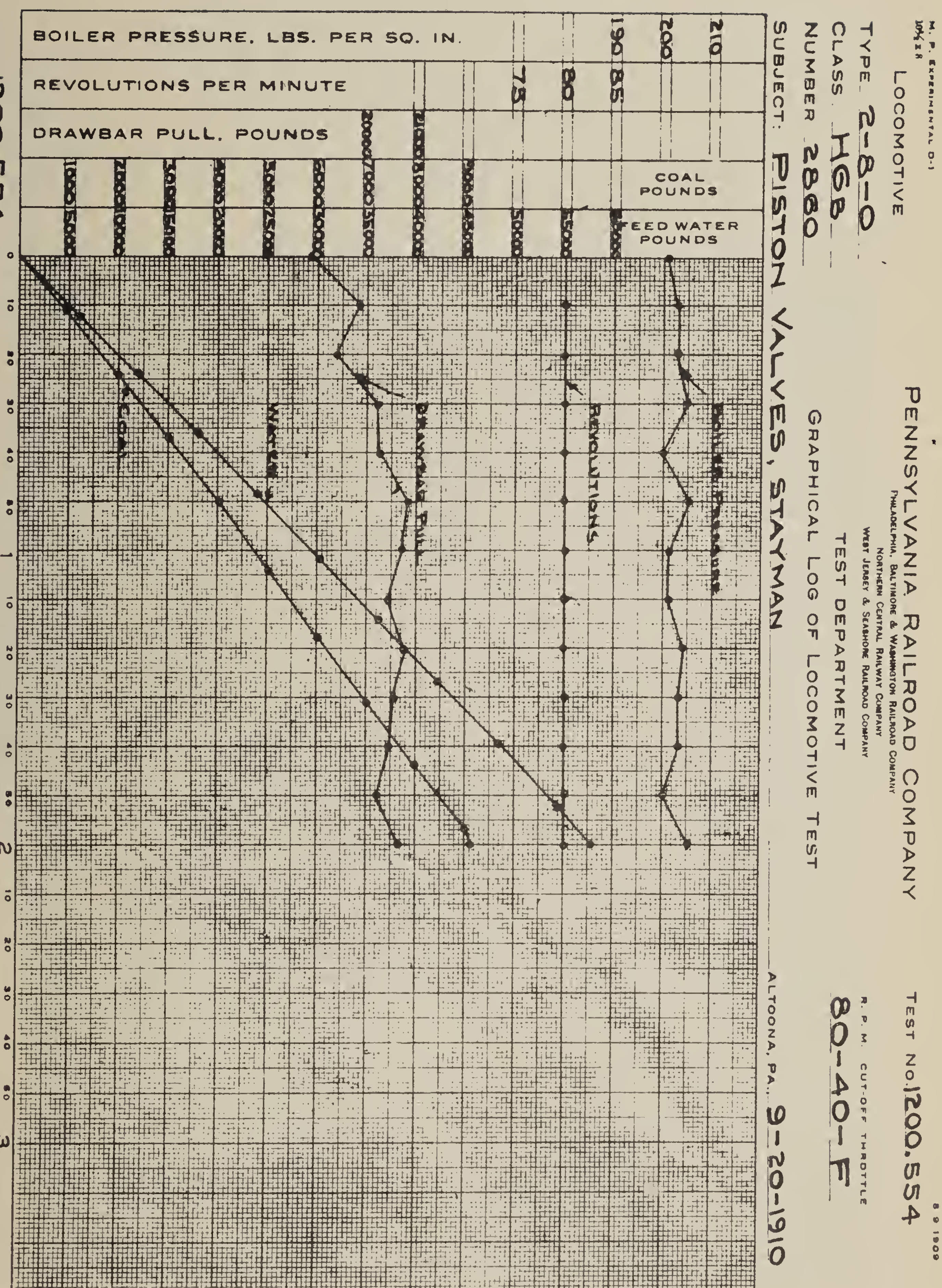

M. P. EXPERIMENTAL D-1
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test No. 1200.528
Locomotive
Type 2-8-0
Class H6b
Number 2860
Test Department
Graphical Log of Locomotive Test
R. P. M. Cut-off Throttle
120-40-F
Subject: Piston Valve, American Semi-Plug
Altoona, Pa. 8-11-1910
Boiler Pressure, lbs. per sq. in.
Revolutions per minute
Drawbar pull, pounds
Coal pounds
Feed water pounds
Steam Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of test—minutes and hours
1200.528

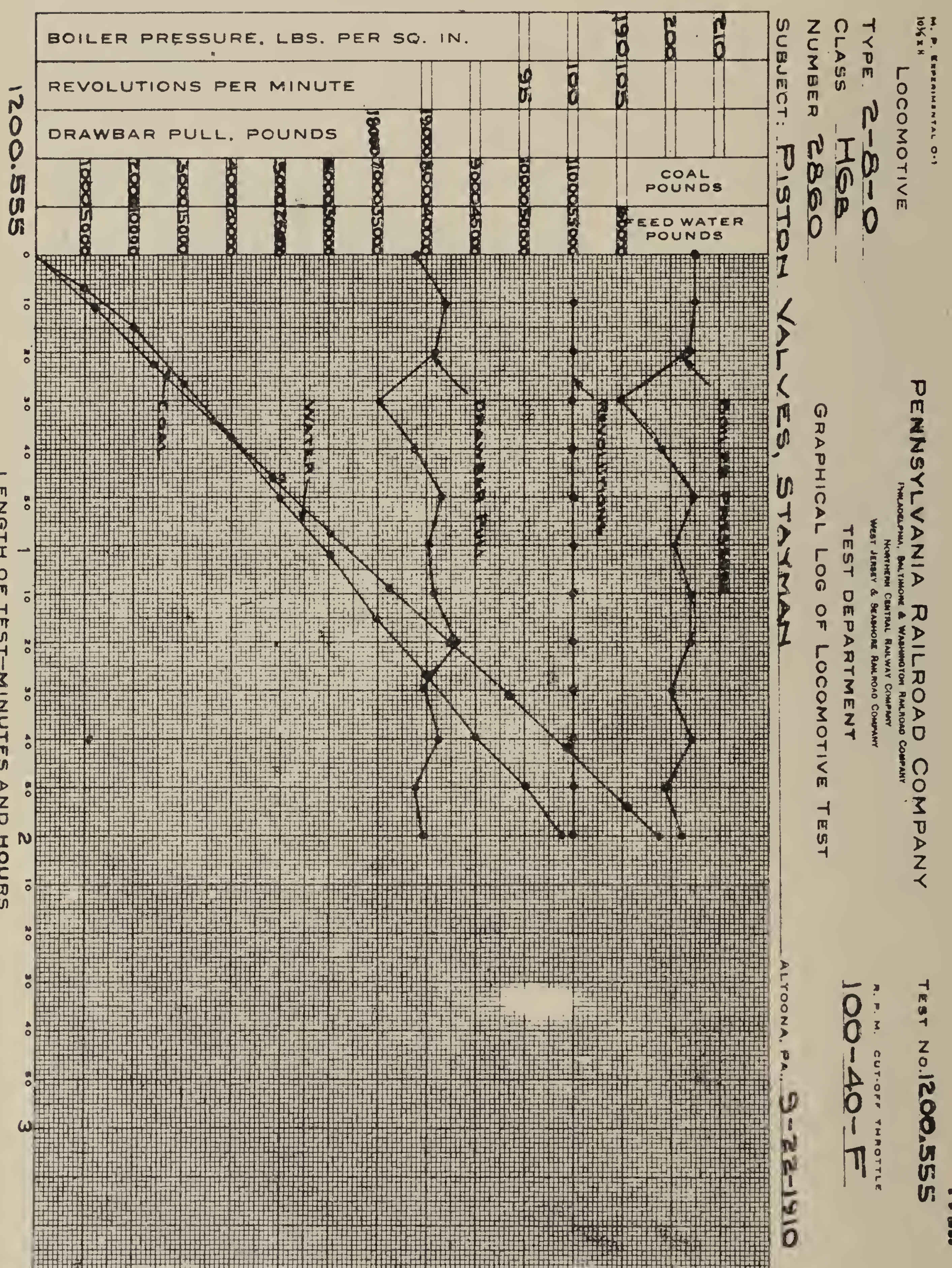

M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVE, AMERICAN SEMI-PLUG
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 1200.529
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA. 8-12-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
STEAM PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.529

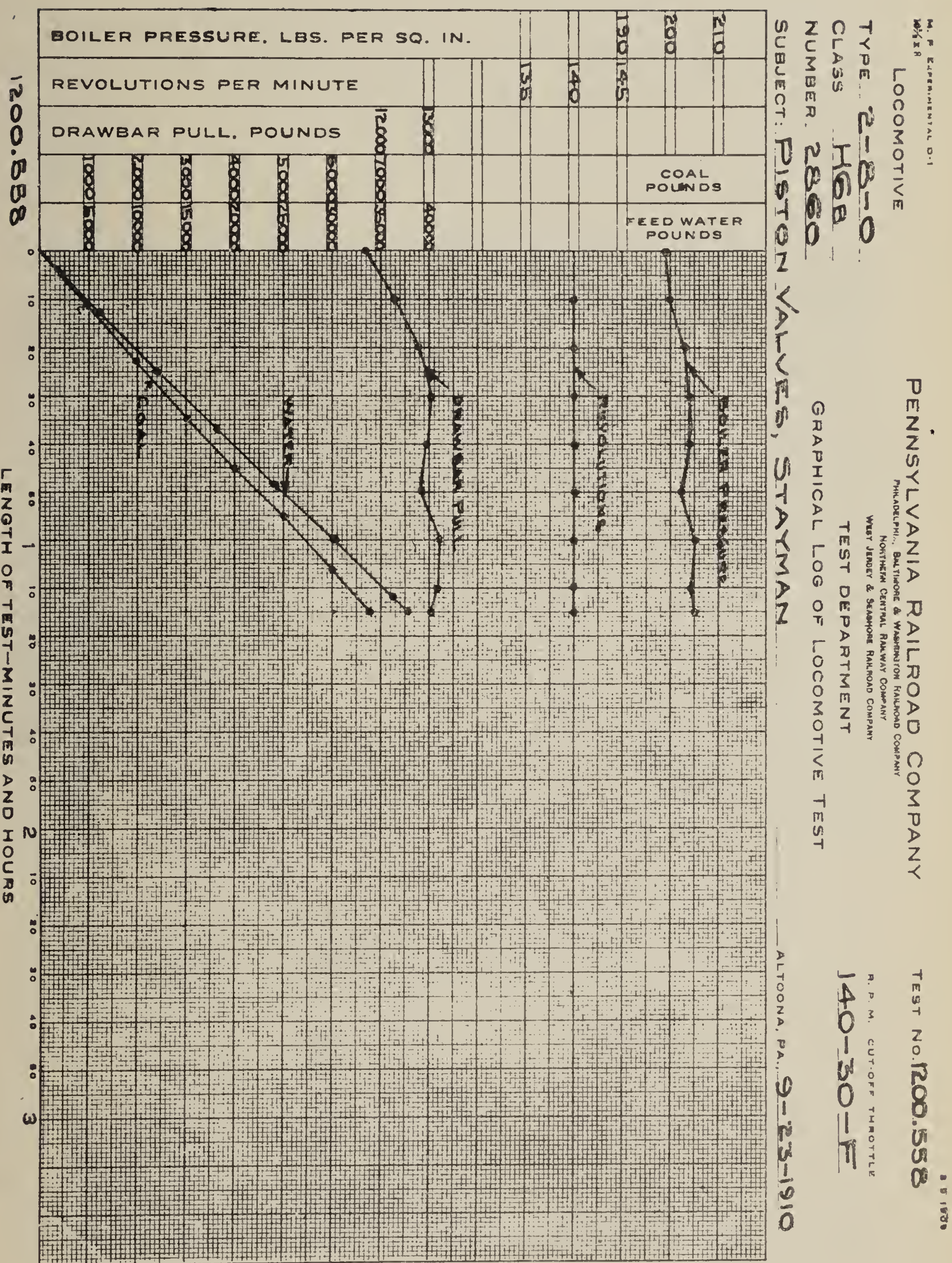

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.530
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2890
R. P. M. CUT-OFF THROTTLE
160-30-F
SUBJECT: PISTON VALVE, AMERICAN SEMI-PLUG
ALTOONA, PA., 8-12-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.530

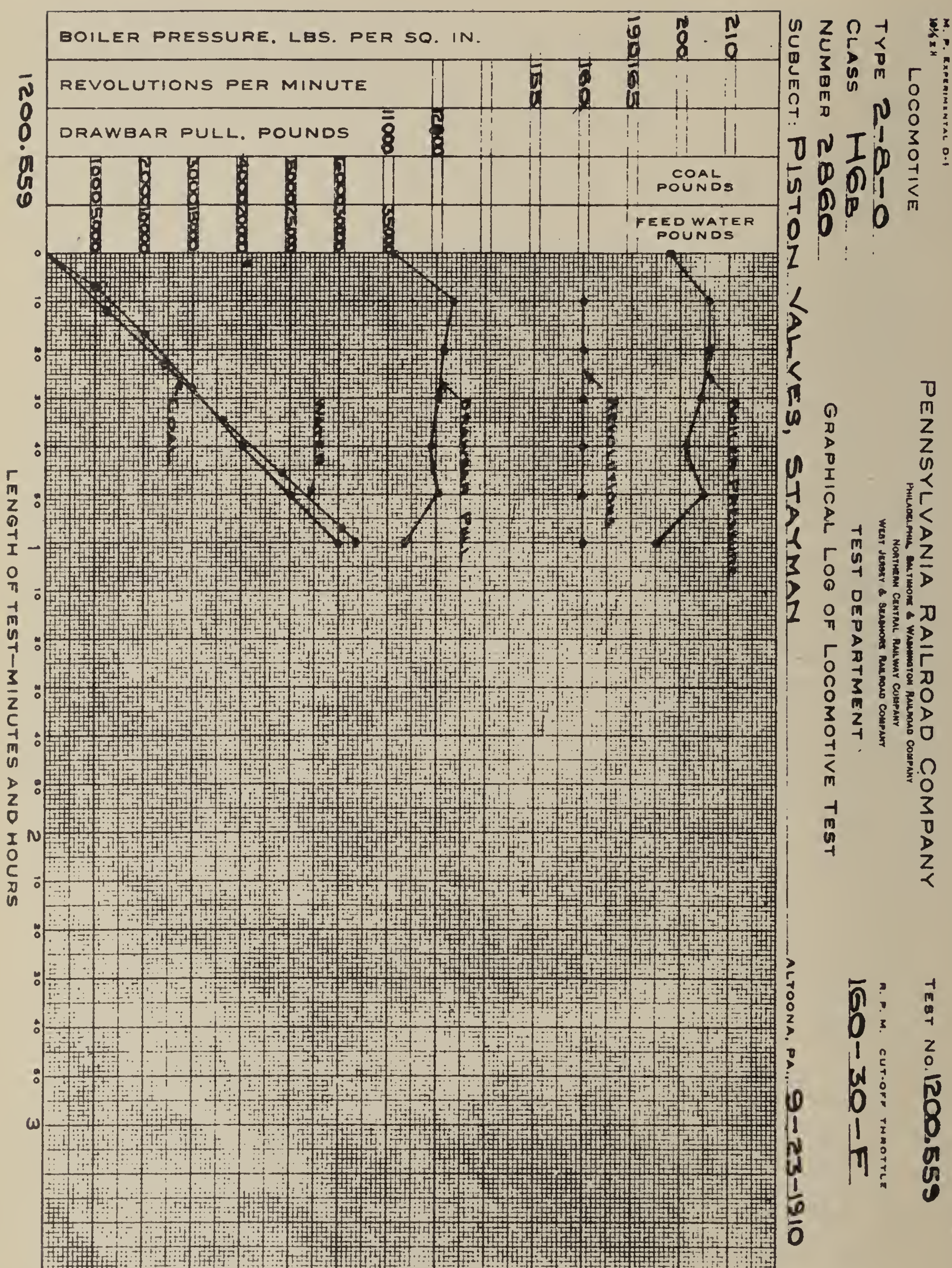

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, STAYMAN
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.556
R. P. M. CUT-OFF THROTTLE
40-20-F
ALTOONA, PA. 9-21-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
45
40
35
10000
9000
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.556

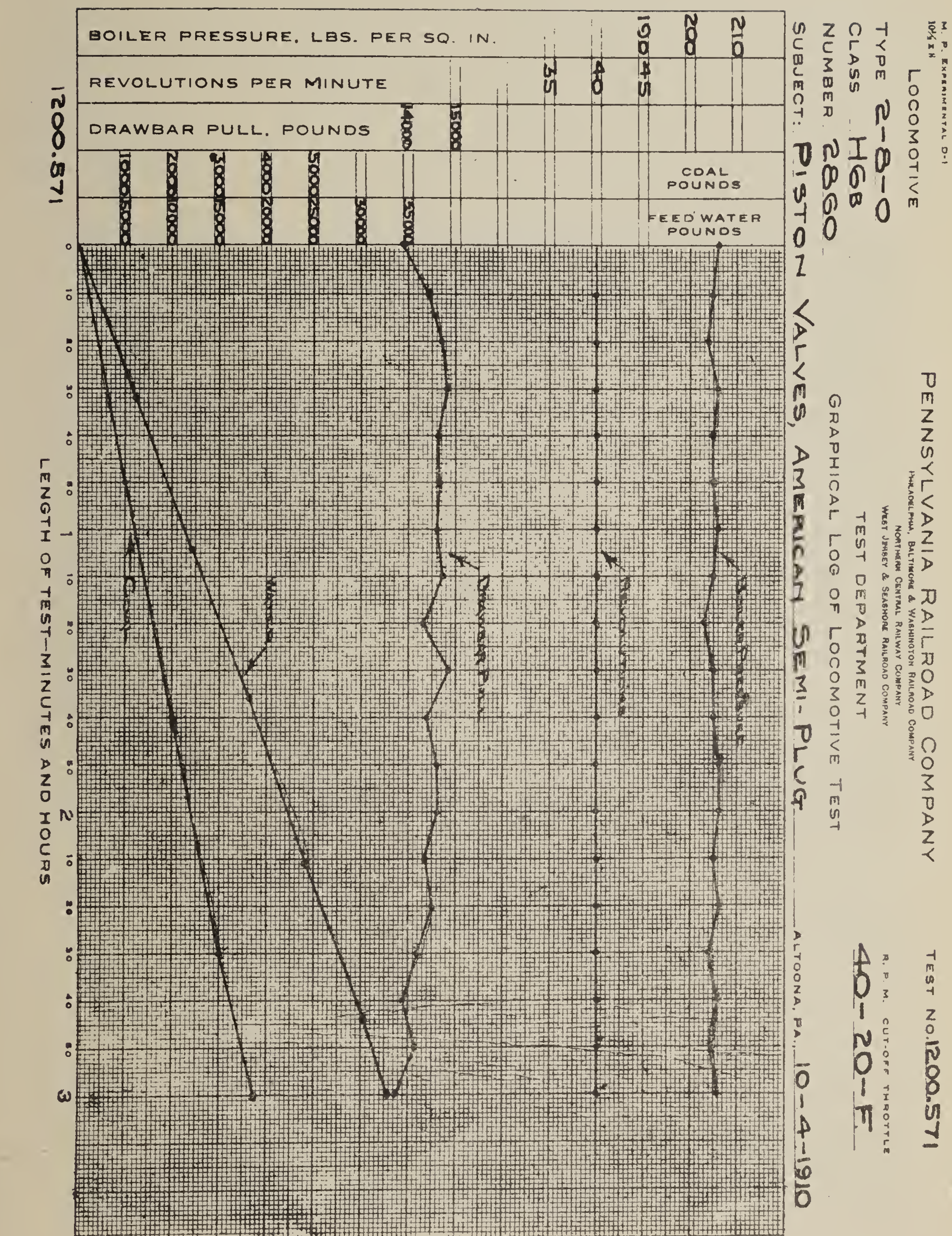

M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 2860
Subject: Piston Valves, Statman
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.557
R. P. M. Cut-off Throttle
60-20-F
Altoona, Pa., 9-22-1910
Boiler Pressure Lbs. Per Sq. In.
Revolutions Per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
1200.557

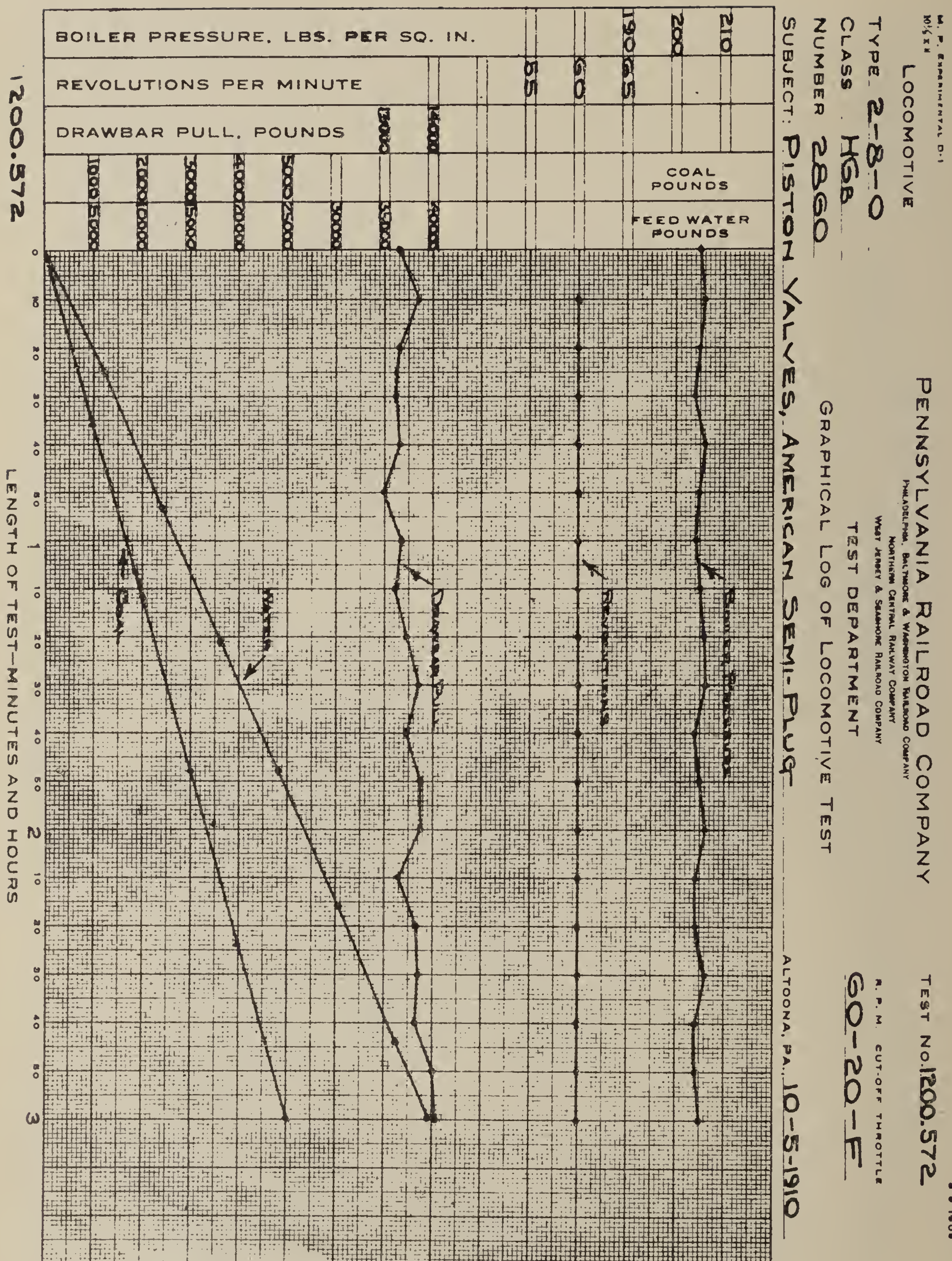

M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, STAYMAN
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.554
R. P. M. CUT-OFF THROTTLE
80-40-F
ALTOONA, PA., 9-20-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
85
80
75
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
1200.554
LENGTH OF TEST—MINUTES AND HOURS
1
2
3

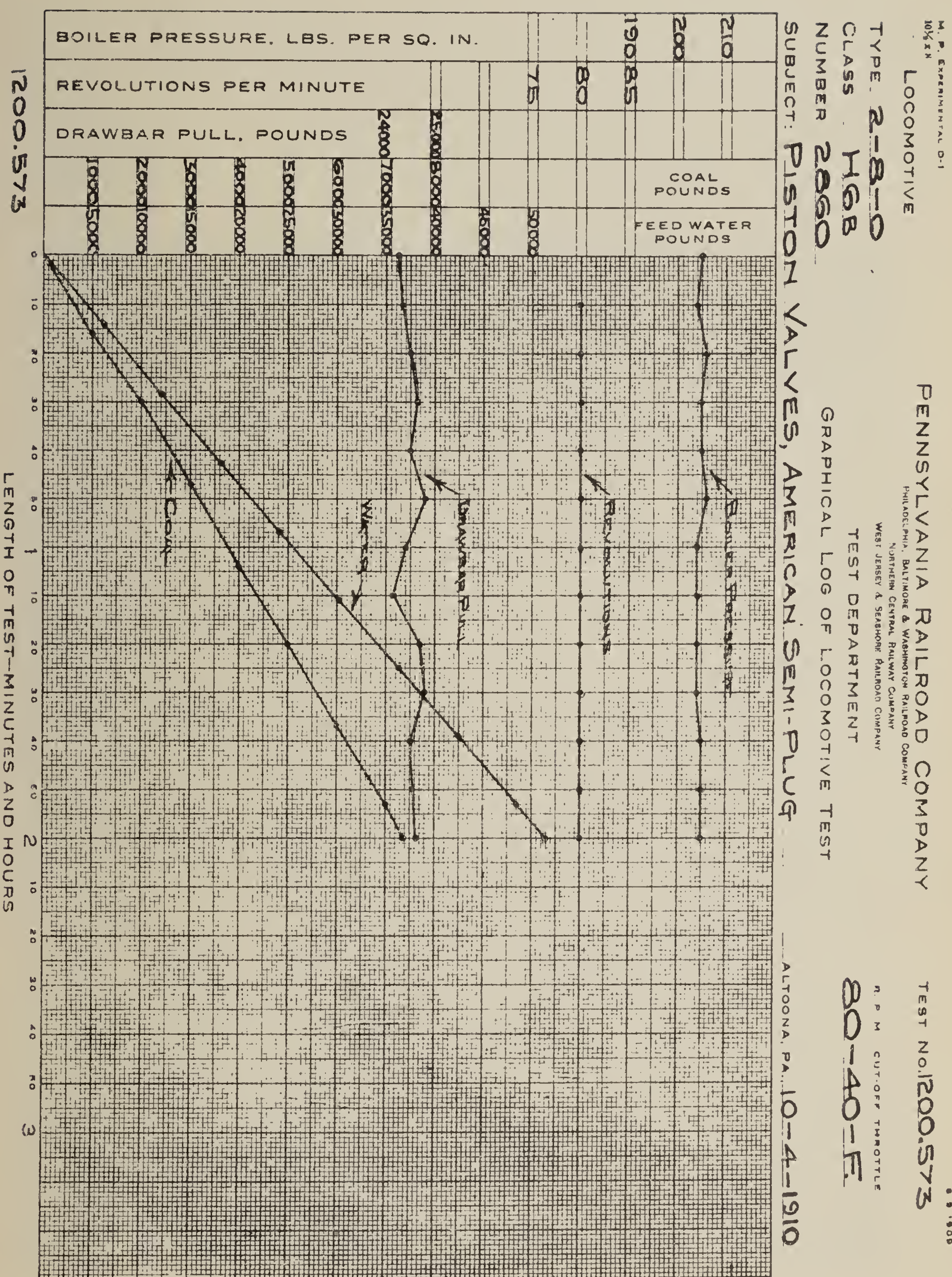

M. P. EXPERIMENTAL O-1
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.555
R. P. M. CUT-OFF THROTTLE
100-40-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, STAYMAN
ALTOONA, PA. 9-22-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.555


PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 1200.558
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, STAYMAN
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA. 9-23-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1200.558

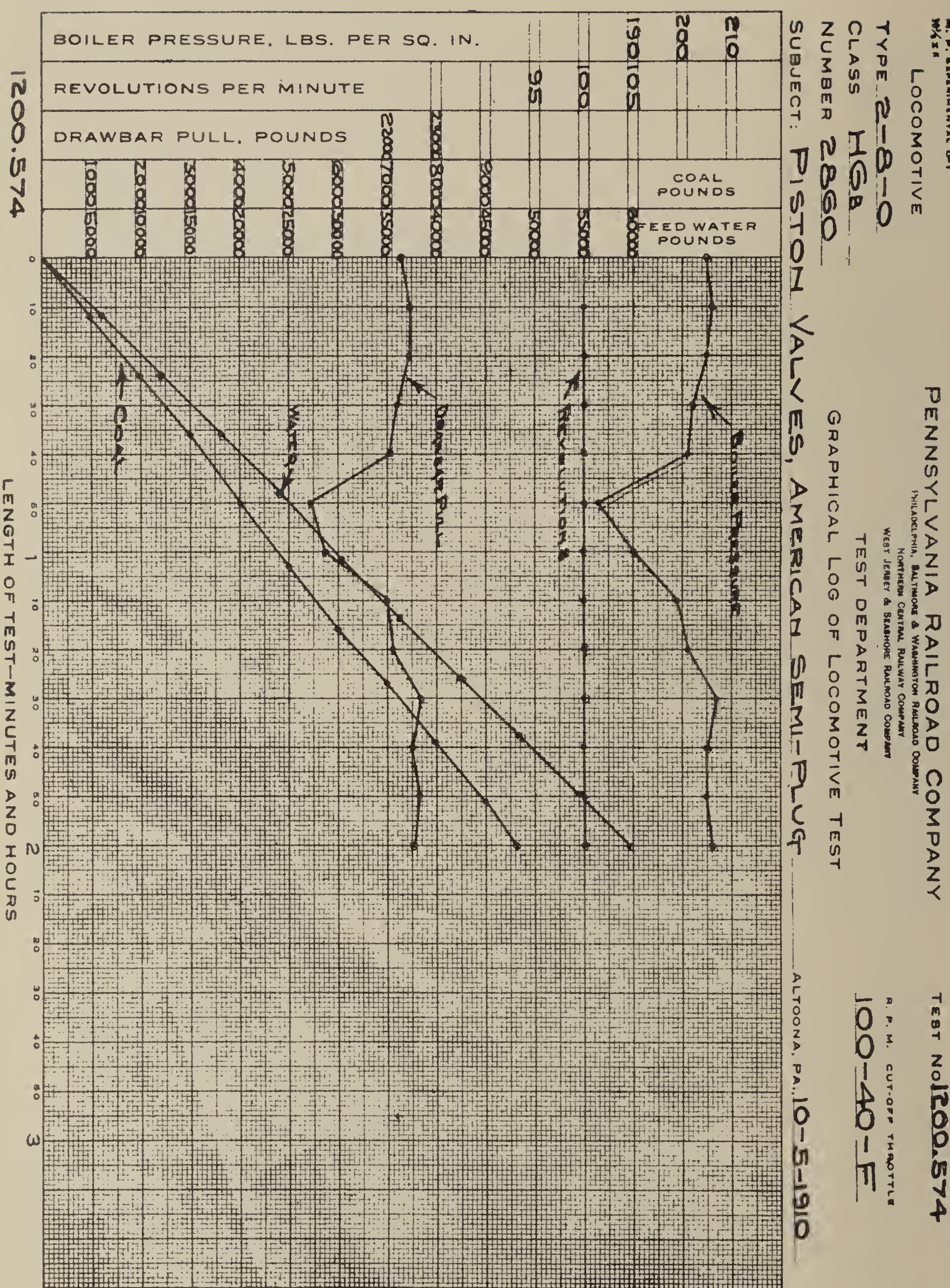

M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6b
Number 2860
Subject: Piston Valves, Stayman
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.559
R. P. M. Cut-off Throttle
160-30-F
Altoona, Pa. 9-23-1910
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
1200.559

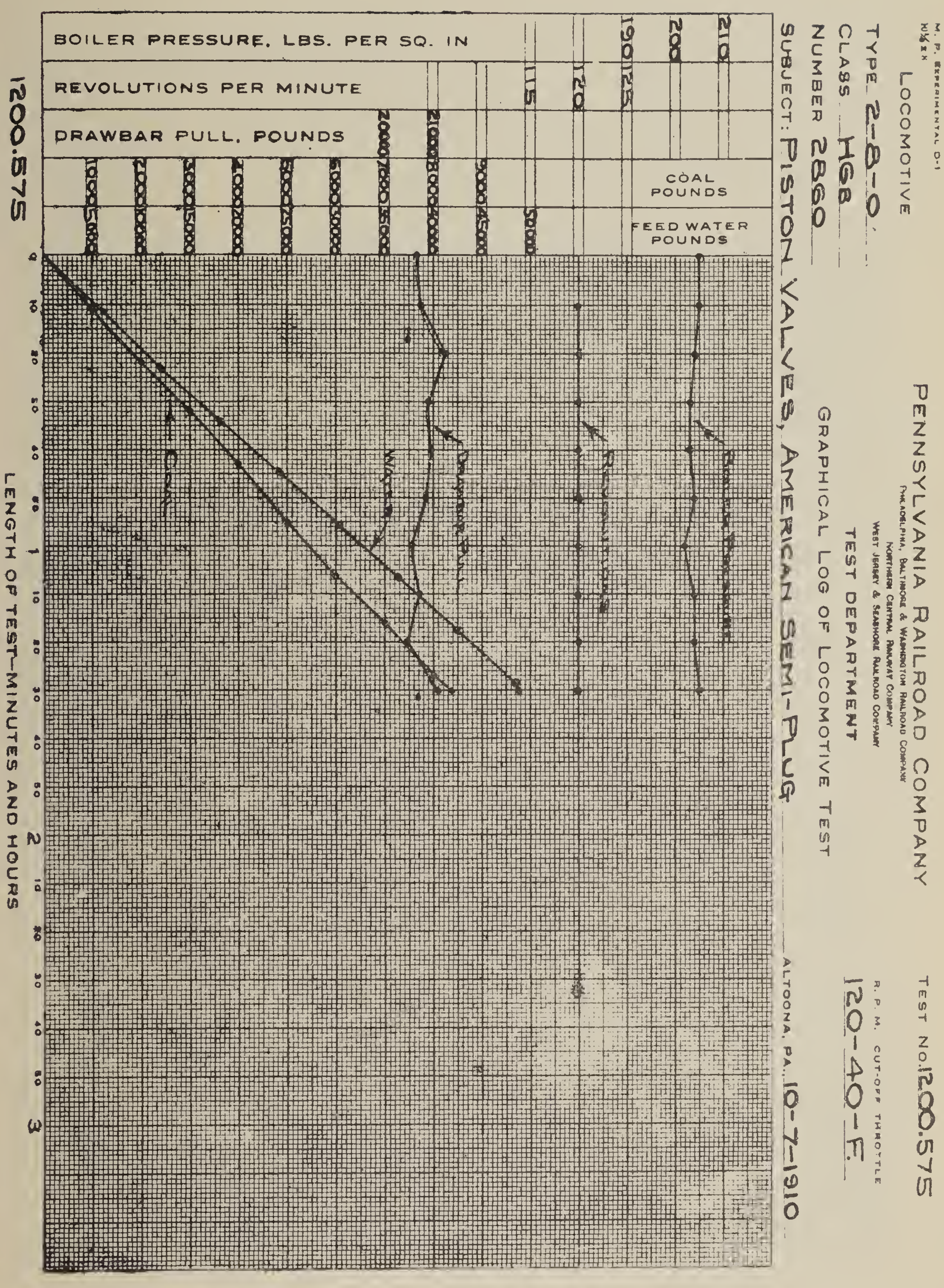

M. P. EXPERIMENTAL D-1
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.571
40 - 20 - F
R. P. M. CUT-OFF THROTTLE
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
ALTOONA, PA., 10-4-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
45
40
35
15000
14000
1000
5000
2000
10000
3000
15000
4000
20000
5000
25000
30000
35000
Coal
Water
Drawbar Pull
Revolutions
LENGTH OF TEST—MINUTES AND HOURS
1
2
3
1200.571

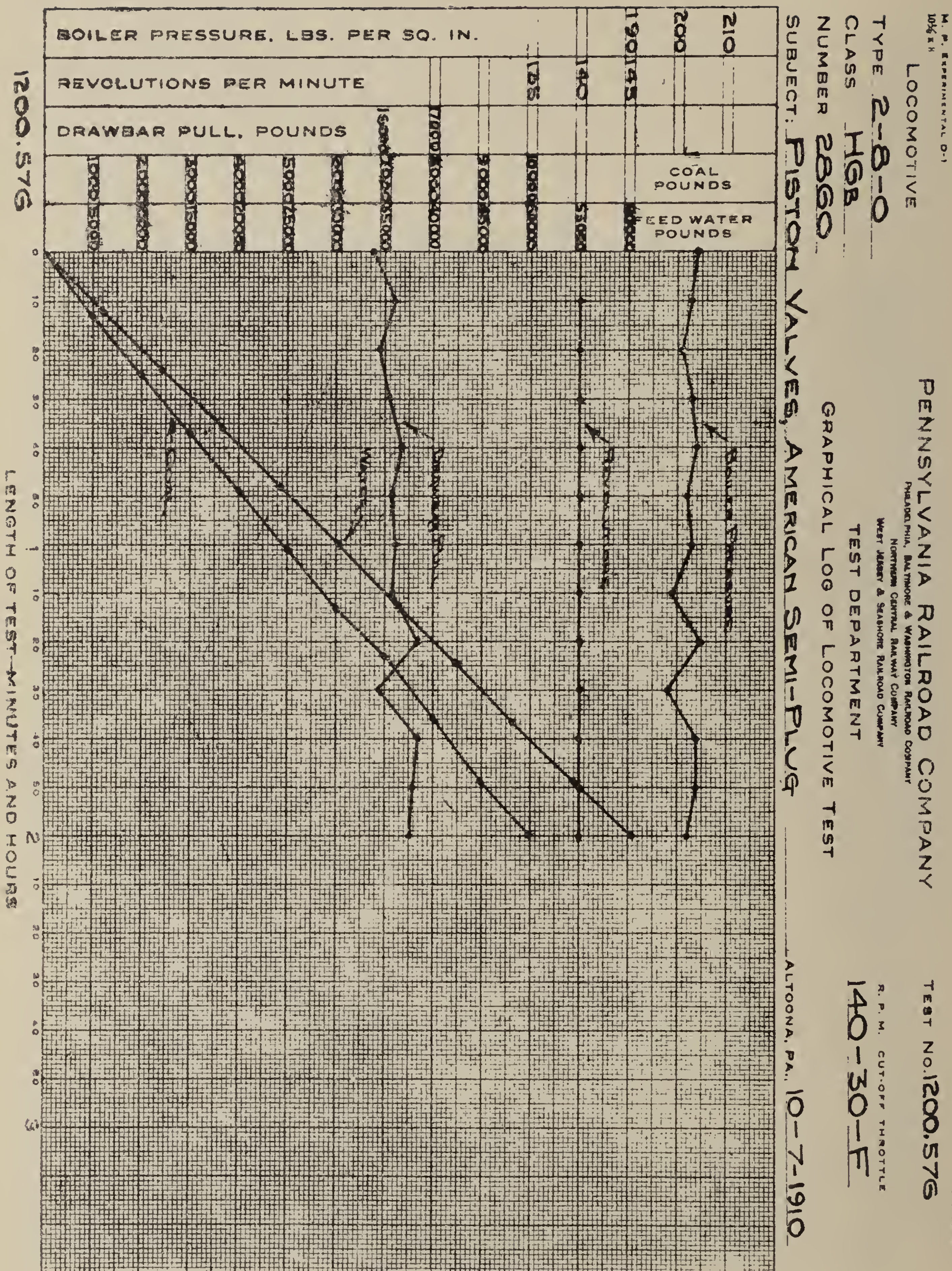

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.572
R. P. M. CUT-OFF THROTTLE
60-20-F
ALTOONA, PA. 10-5-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
65
60
55
14000
13000
1000 5000
2000 10000
3000 15000
4000 20000
5000 25000
30000
35000
40000
LENGTH OF TEST—MINUTES AND HOURS
1200.572

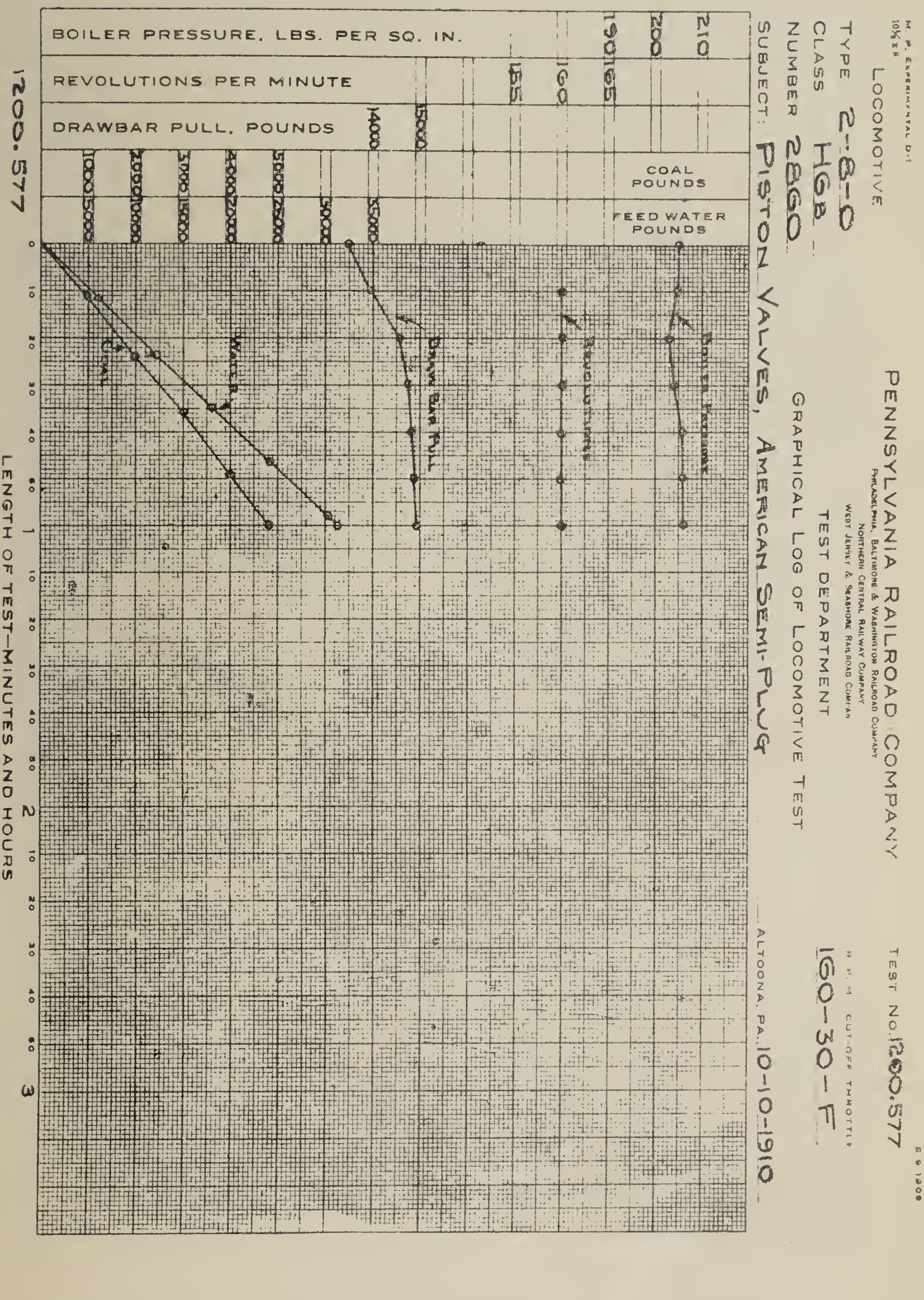


Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.573
R. P. M. Cut-off Throttle
80-40-F.
Locomotive
Type 2-8-0
Class H6B
Number 2860
Subject: Piston Valves, American Semi-Plug
Altoona, Pa. 10-4-1910
Boiler Pressure, Lbs. per sq. in.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
1200.573

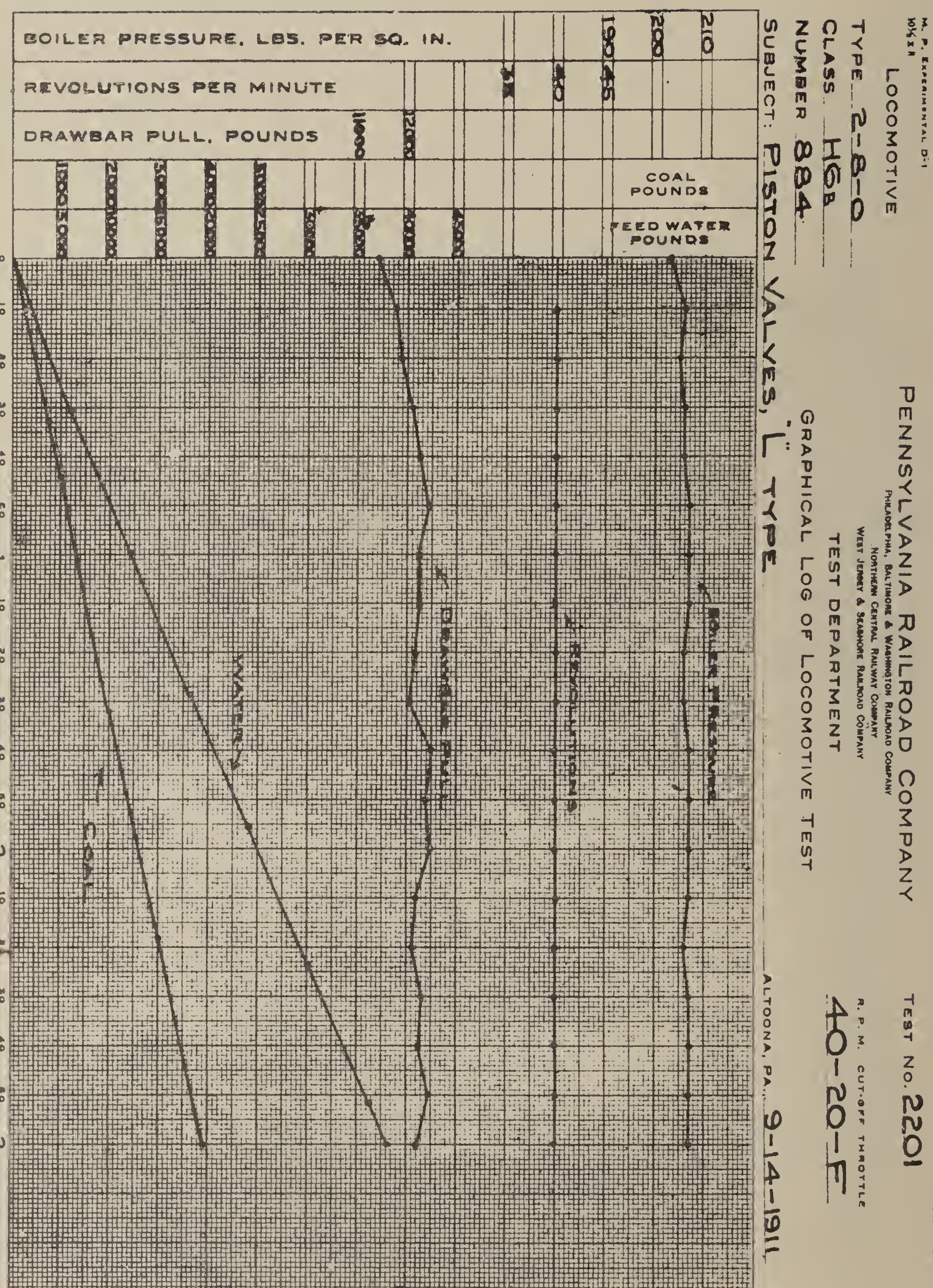

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No 1200.574
R. P. M. CUT-OFF THROTTLE
100-40-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
ALTOONA, PA. 10-5-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
1200.574

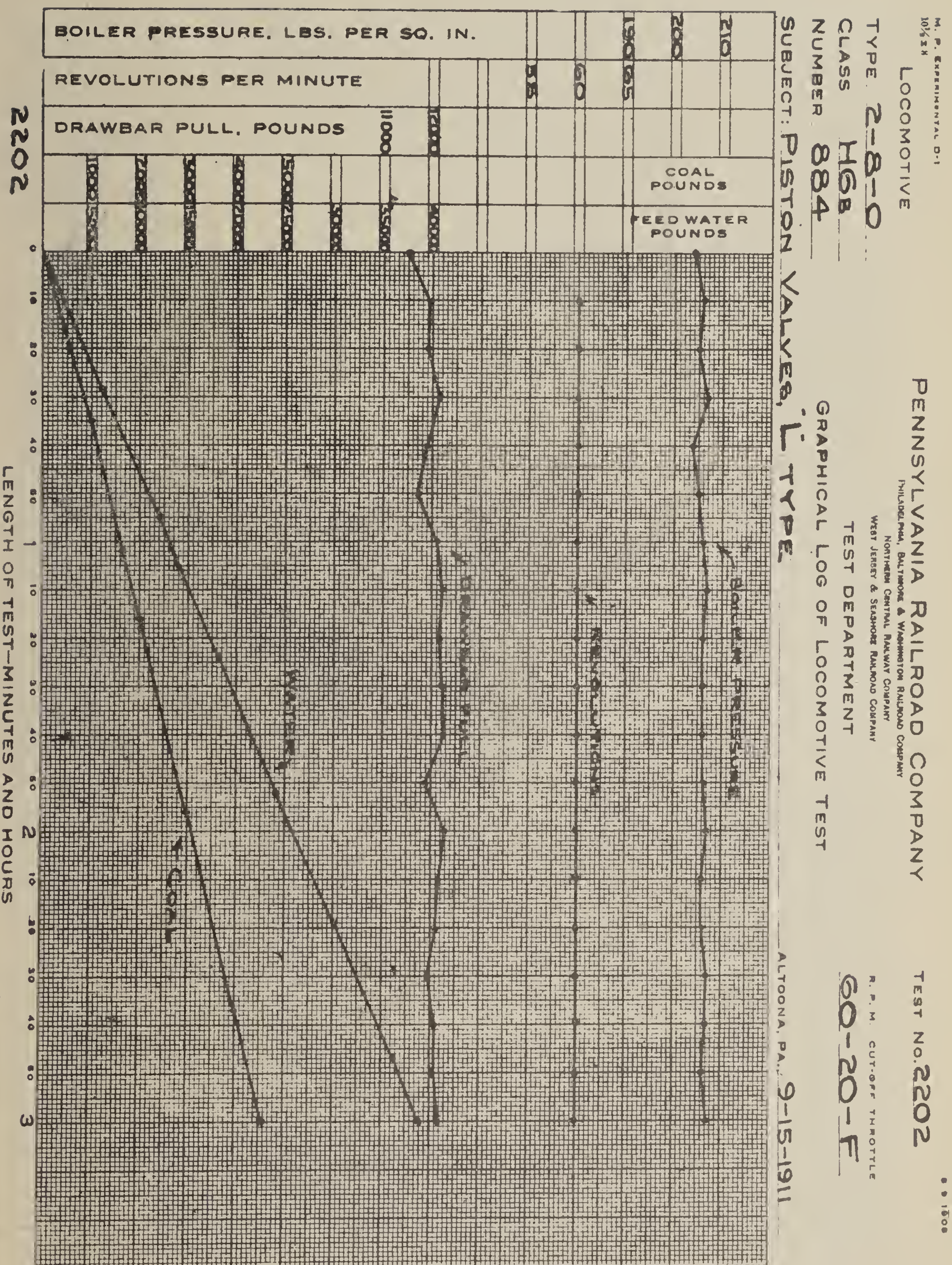

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 1200.575
R. P. M. CUT-OFF THROTTLE
120-40-F.
ALTOONA, PA. 10-7-1910
BOILER PRESSURE, LBS. PER SQ. IN
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
LENGTH OF TEST—MINUTES AND HOURS
1200.575


PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.576
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
ALTOONA, PA. 10-7-1910
140-30-F
R. P. M. CUT-OFF THROTTLE
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
LENGTH OF TEST—MINUTES AND HOURS
1200.576

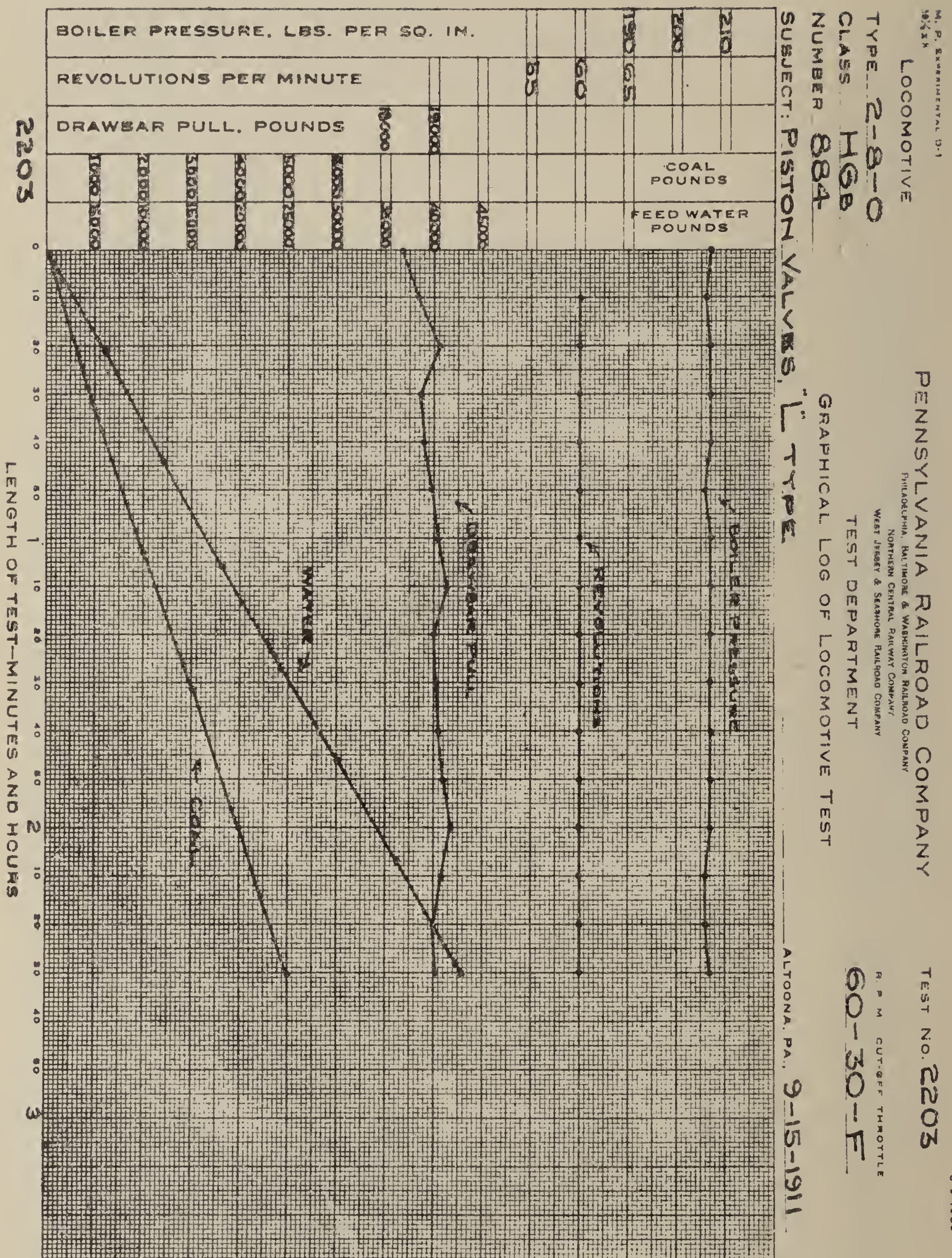


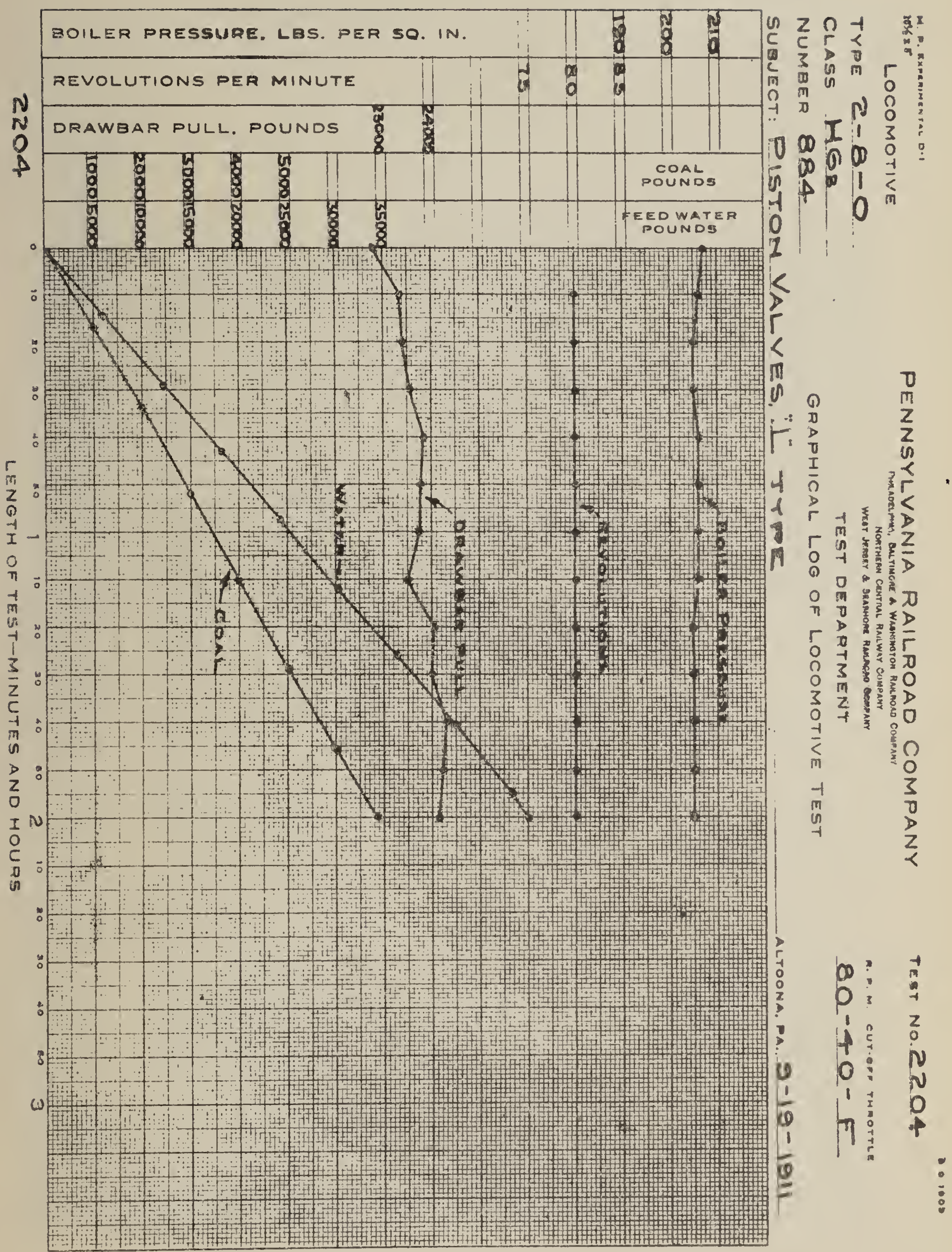
M. P. EXPERIMENTAL D-1
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.577
160-30-F
R. P. M. CUT-OFF THROTTLE
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: PISTON VALVES, AMERICAN SEMI-PLUG
ALTOONA, PA. 10-10-1910
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
165
160
155
15000
14000
Boiler Pressure
Revolutions
Draw Bar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
1
2
3
1200.577

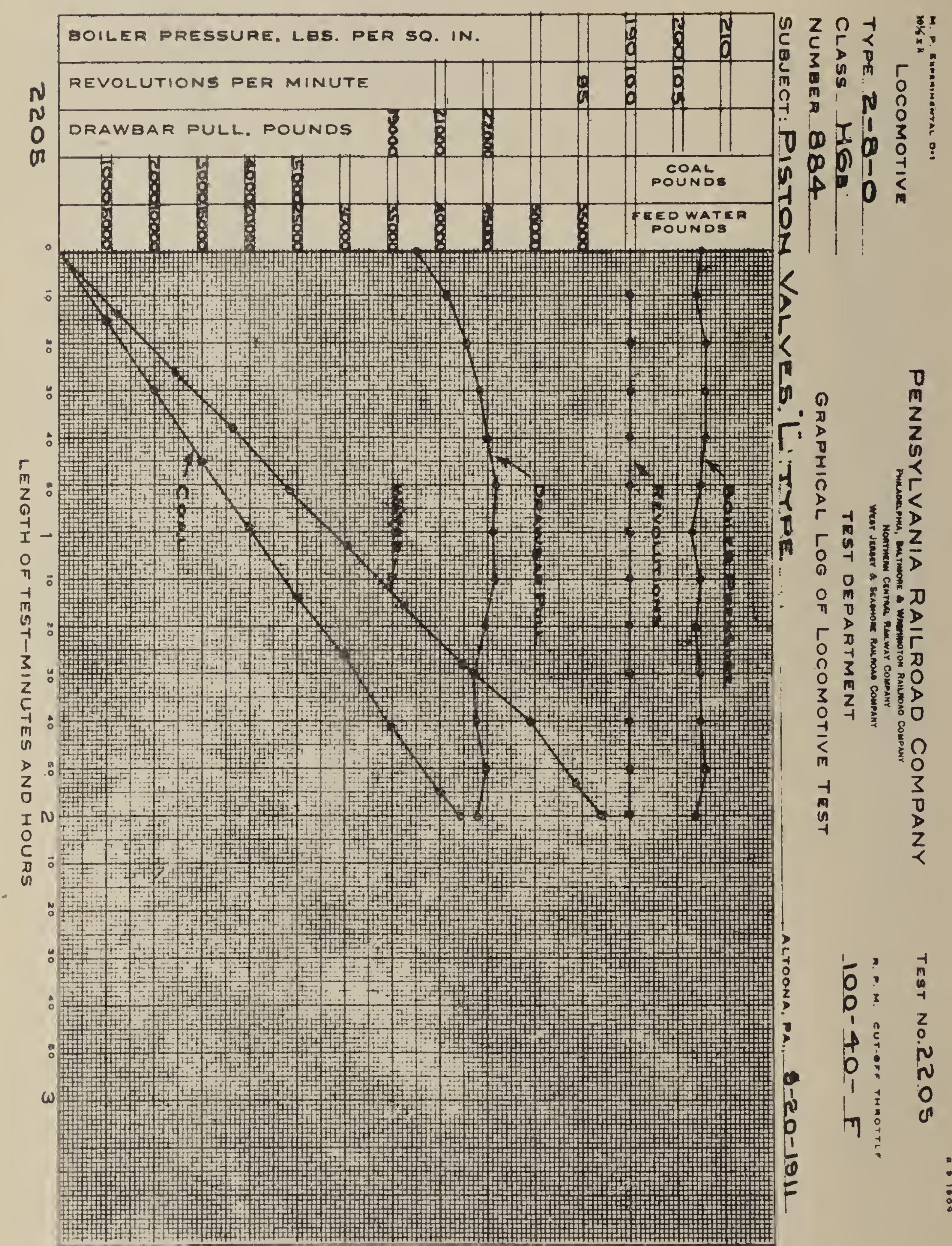

LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2201
R. P. M. CUT-OFF THROTTLE
40-20-F
ALTOONA, PA. 9-14-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2201



M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2202
R. P. M. CUT-OFF THROTTLE
60-20-F
ALTOONA, PA., 9-15-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2202


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2203
60-30-F
R. P. M. CUT-OFF THROTTLE
ALTOONA, PA., 9-15-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2203


M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2204
R. P. M. CUT-OFF THROTTLE
80-40-F
ALTOONA, PA., 9-19-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2204


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2205
100-40-F
R. P. M. CUT-OFF THROTTLE
ALTOONA, PA. 8-20-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2205

M. P. Experimental D-1
10½ x 8

LOCOMOTIVE

TYPE 2-8-0

CLASS H6B

NUMBER 884

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

GRAPHICAL LOG OF LOCOMOTIVE TEST

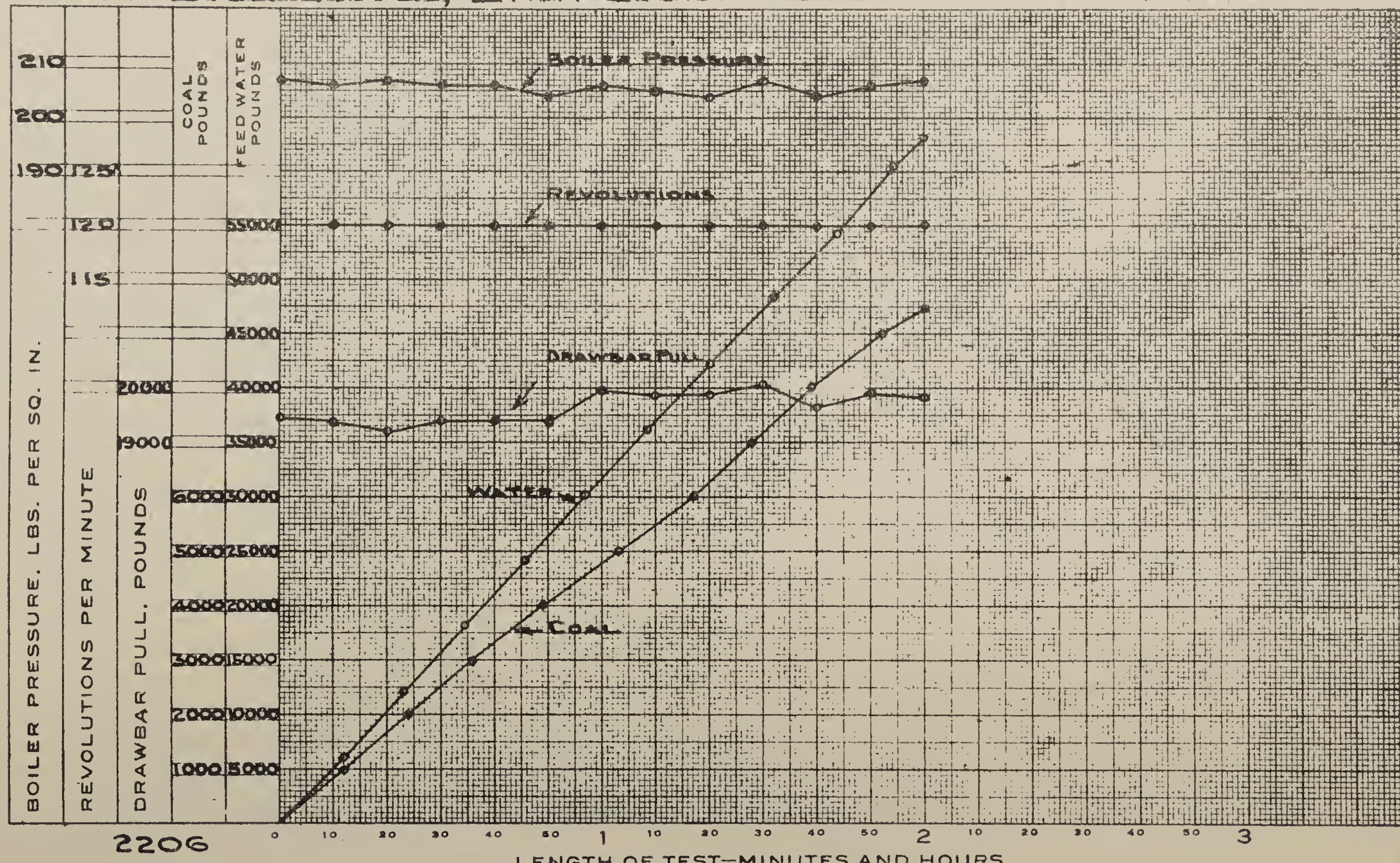
R. B. 1905

TEST No. 2206

R. P. M. CUT-OFF THROTTLE

120-40-F

SUBJECT: PISTON VALVES, "L" TYPE. ALTOONA, PA. 9-20-1911



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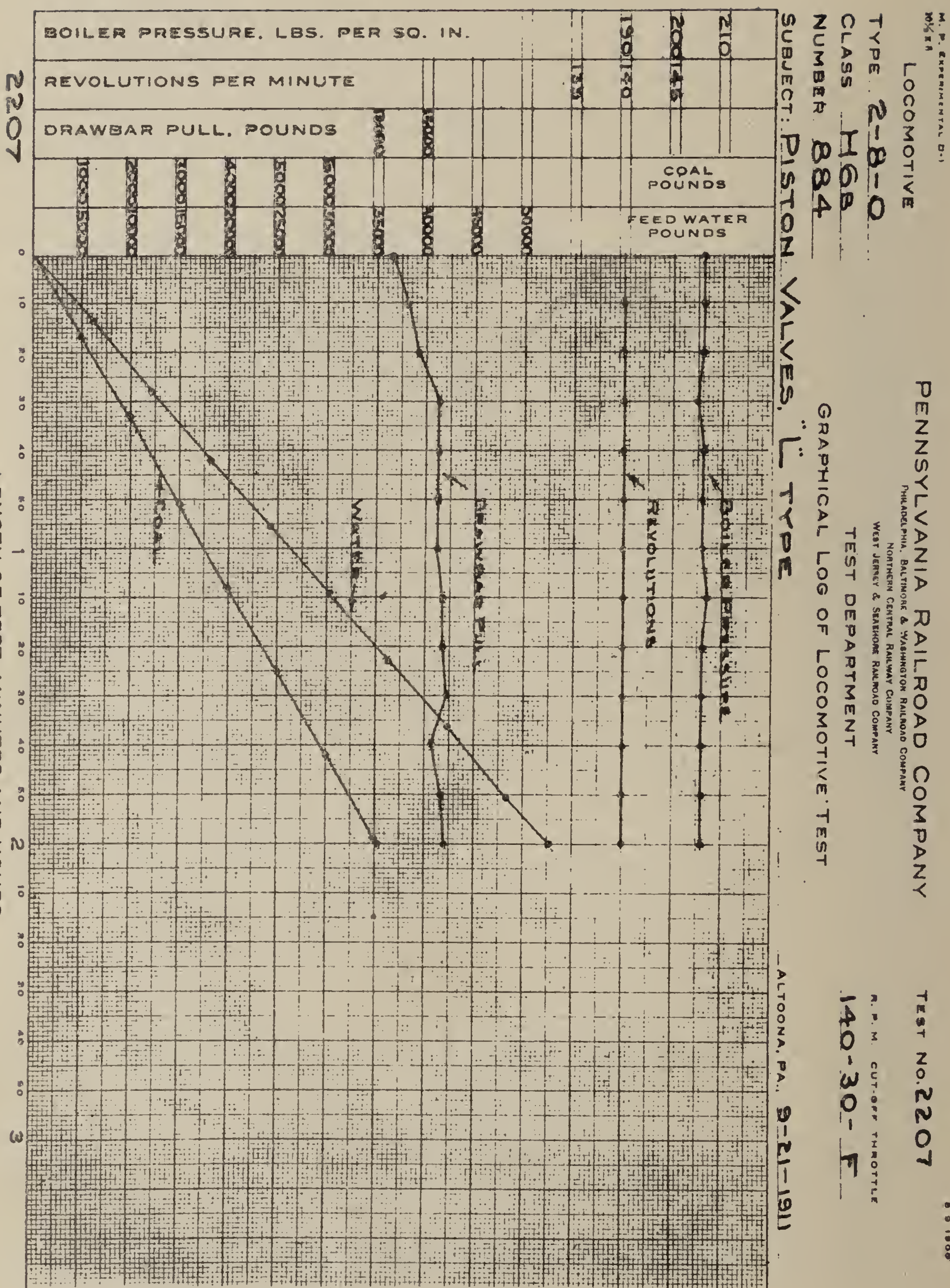
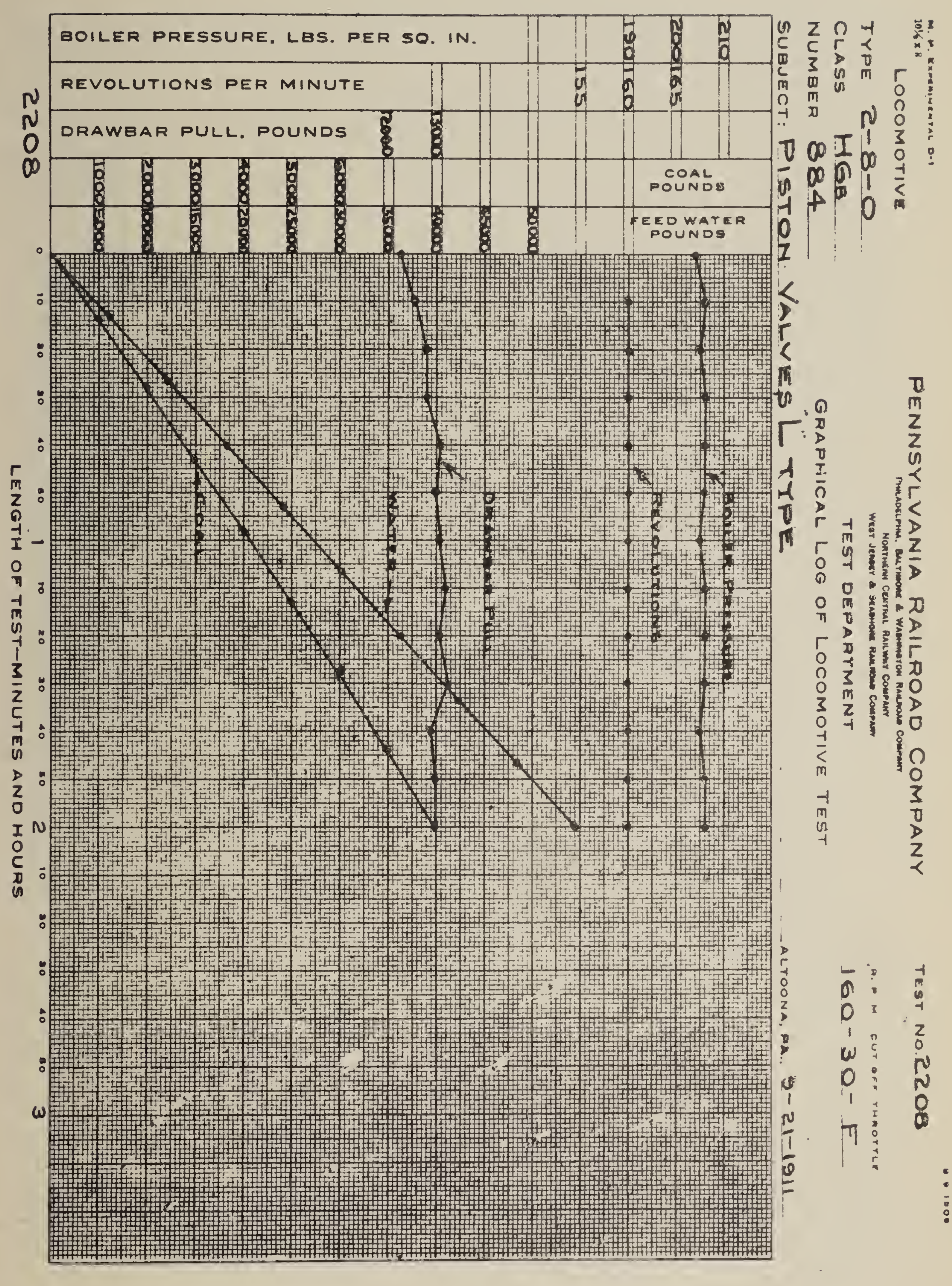
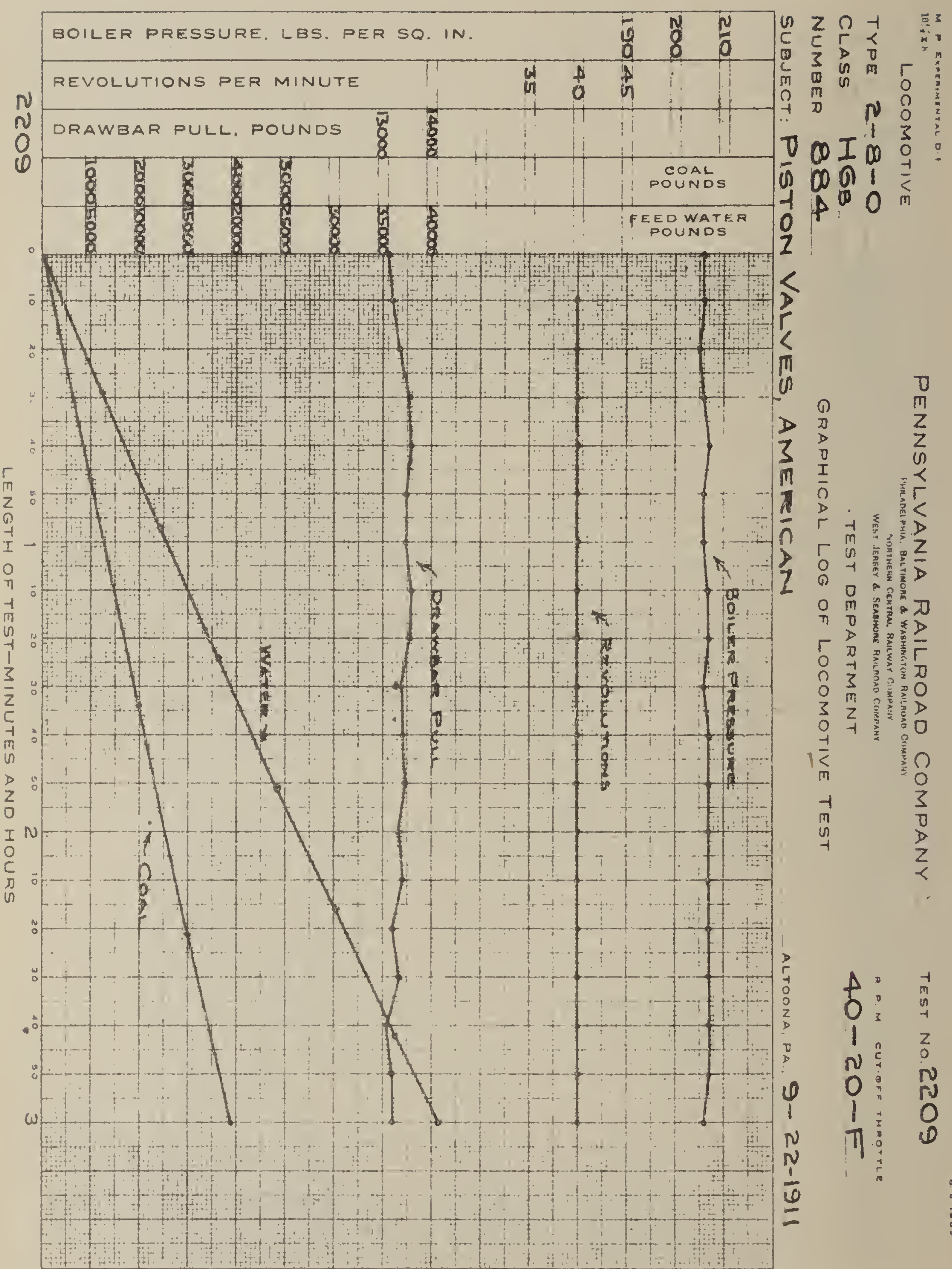
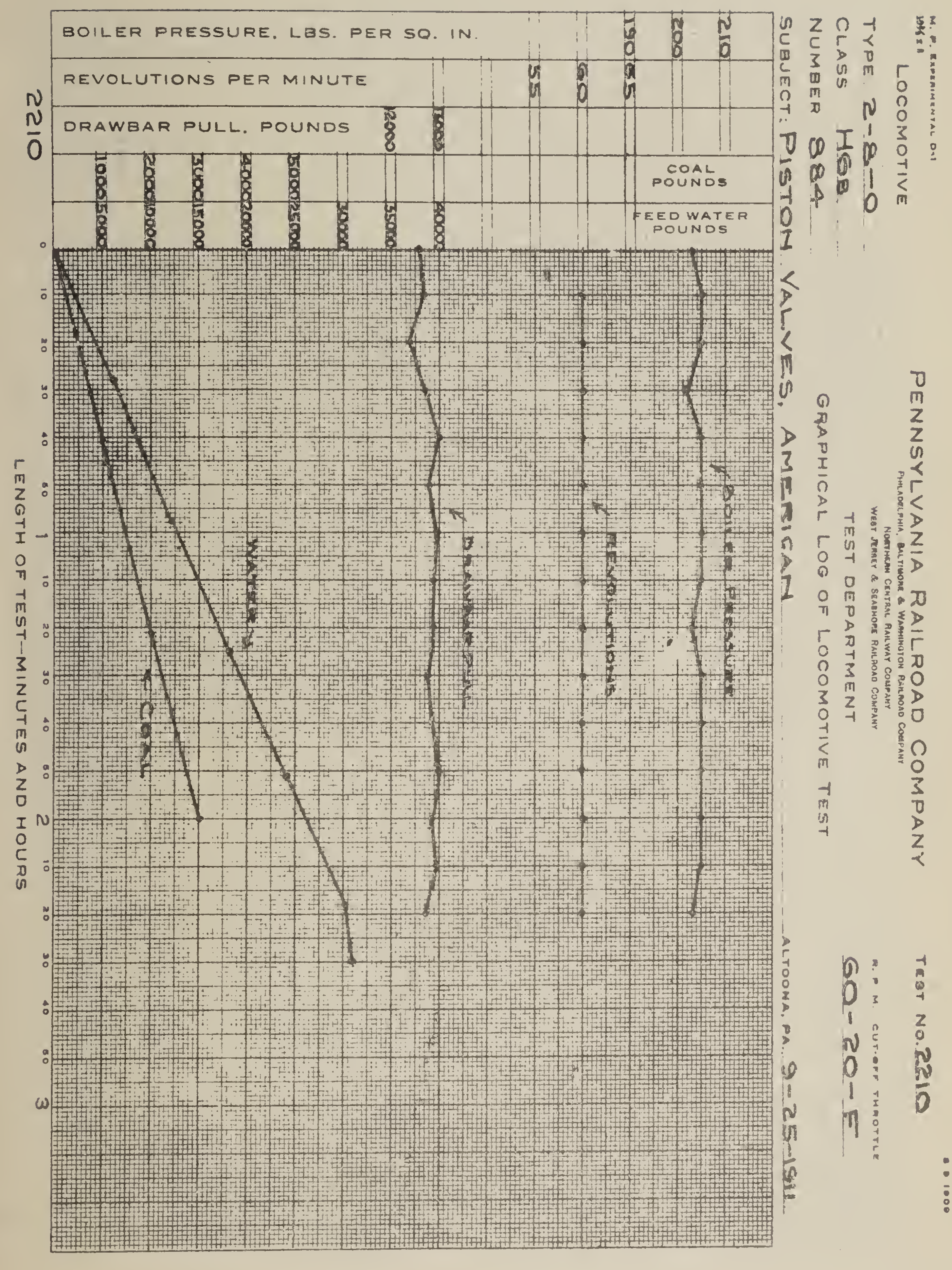
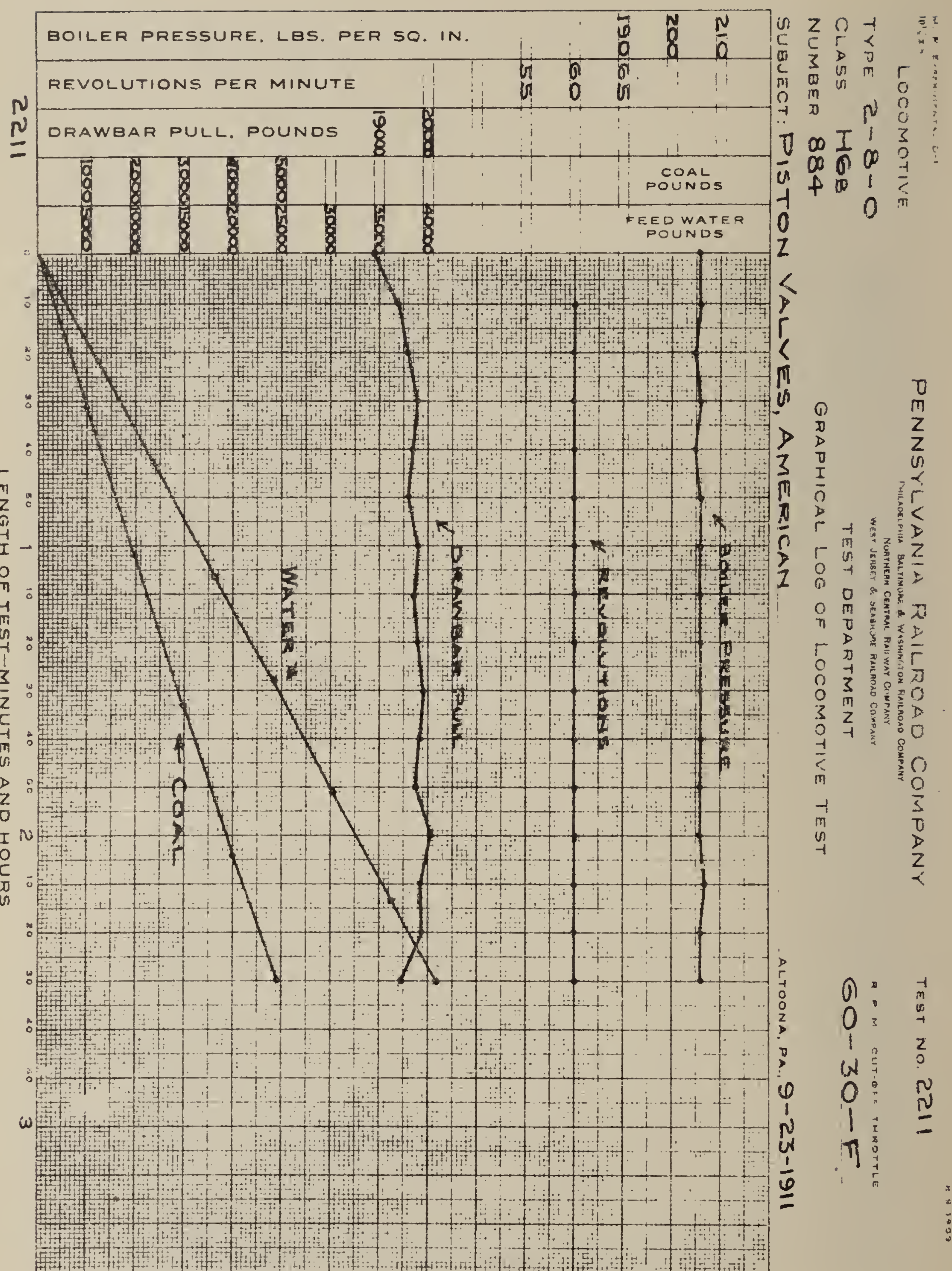


M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2207
R. P. M. CUT-OFF THROTTLE
140-30-F
ALTOONA, PA. 9-21-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
145
140
135
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
1
2
3
2207


M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES "L" TYPE
PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2208
R. P. M. CUT OFF THROTTLE
160-30-F
ALTOONA, PA. 9-21-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
165
160
155
13000
12000
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2208


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, AMERICAN
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 2209
R. P. M. CUT-OFF THROTTLE
40-20-F
ALTOONA, PA. 9-22-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
2209


M. P. Experimental Del
Locomotive
Type 2-8-0
Class H8B
Number 884
Subject: Piston Valves, American
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 2210
R. P. M. Cut-off Throttle
60-20-F
Altoona, Pa. 9-25-1911
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Length of Test—Minutes and Hours
2210


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, AMERICAN
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2211
R P M CUT-OFF THROTTLE
60-30-F
ALTOONA, PA., 9-23-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
65
60
55
20000
19000
1000 5000
2000 10000
3000 15000
4000 20000
5000 25000
30000
35000
40000
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2211

M. P. Experimental D-1
10½ x 8

Locomotive

Type 2-8-0
Class H6B
Number 884
Subject: Piston Valves, American

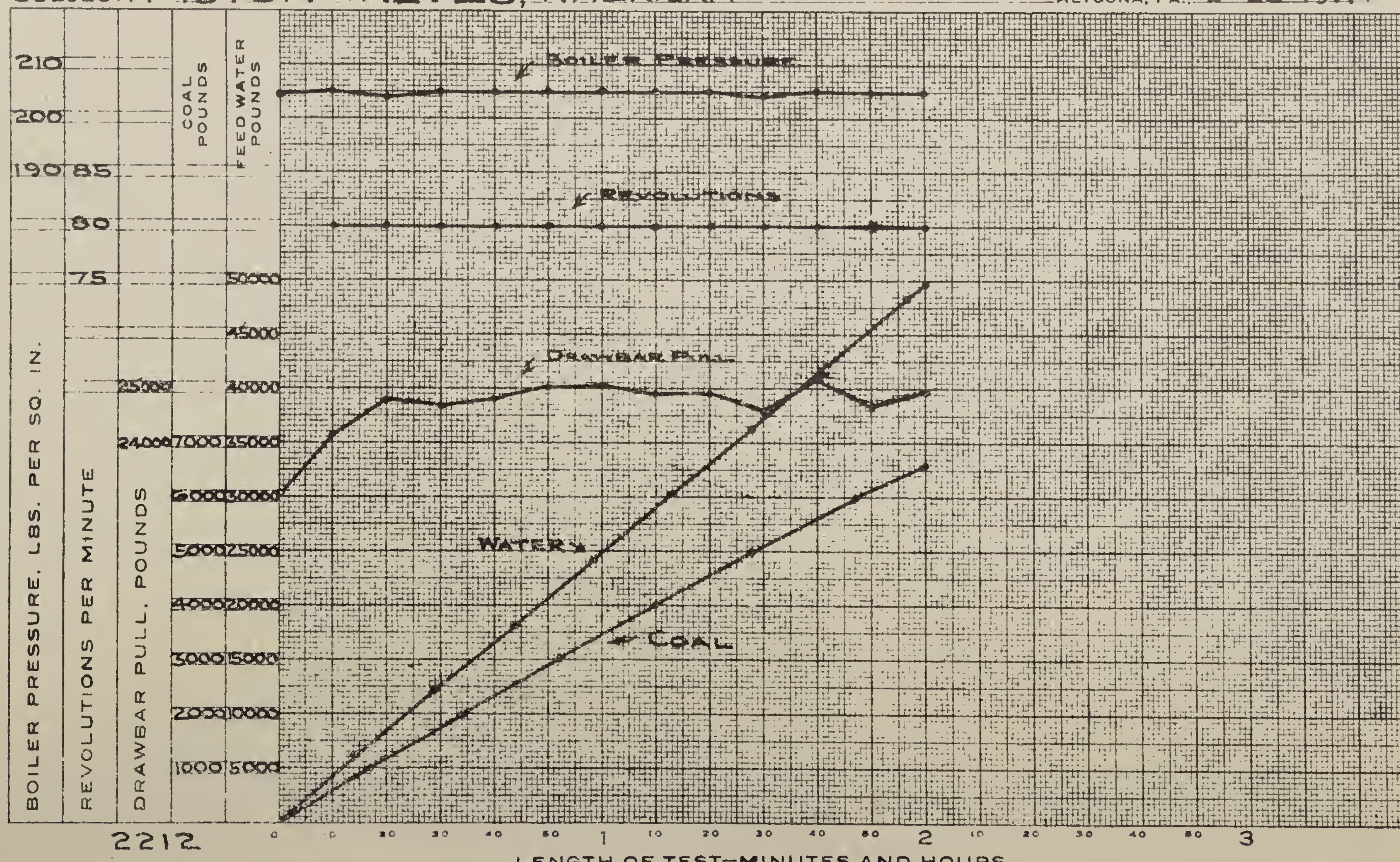
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

Test Department
Graphical Log of Locomotive Test

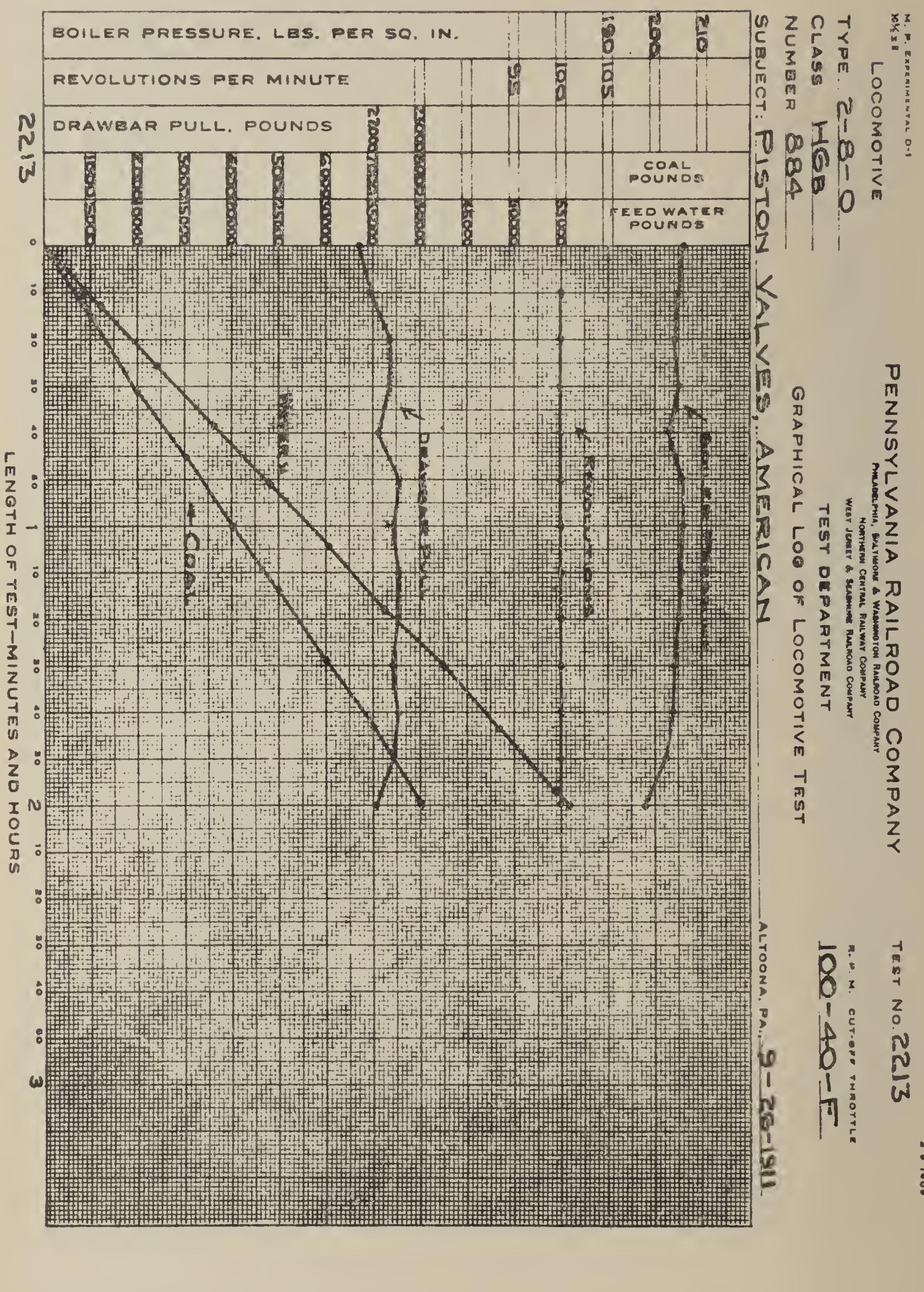
Test No. 2212

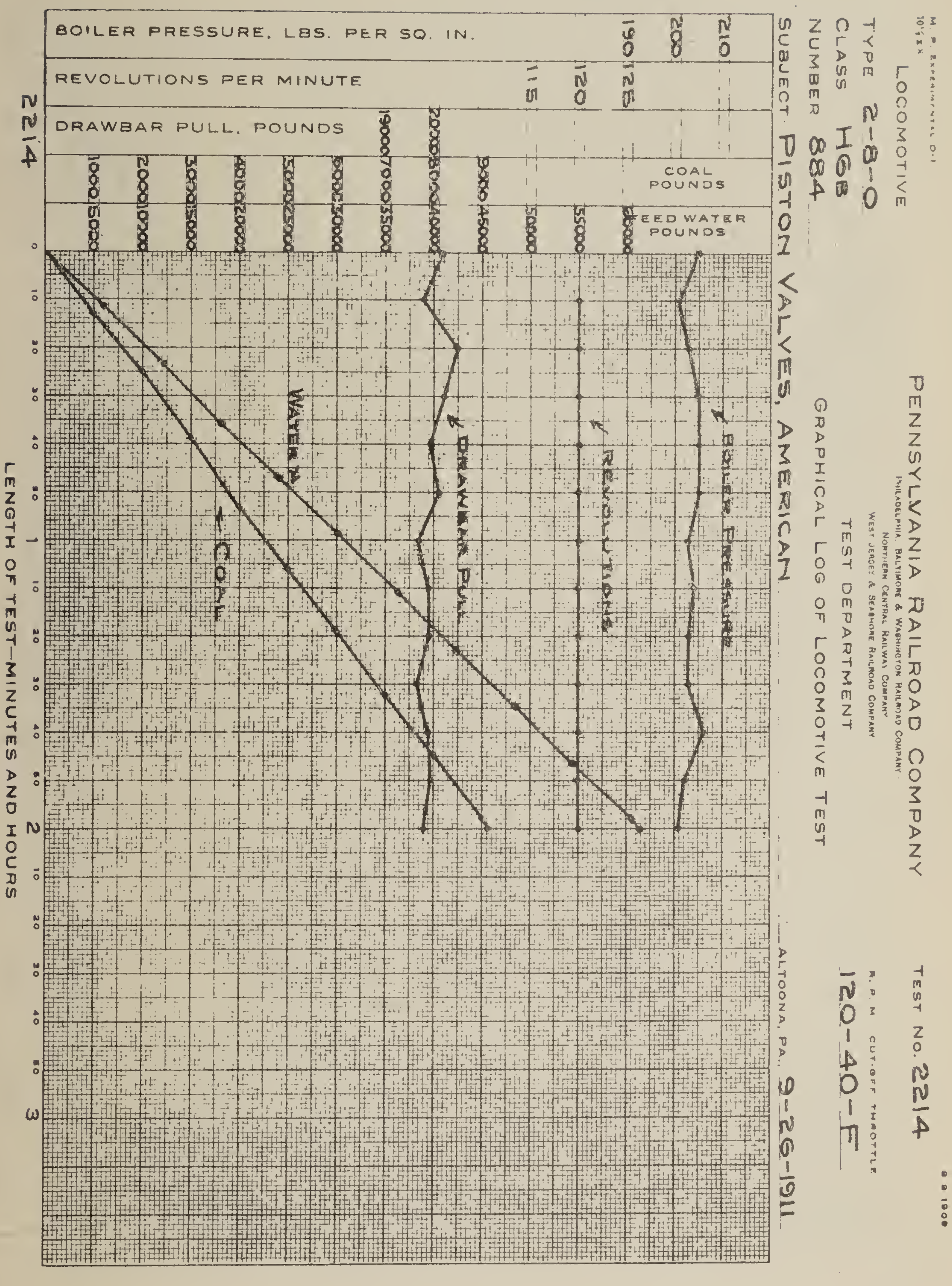
R. P. M. Cut-off Throttle
80-40-F

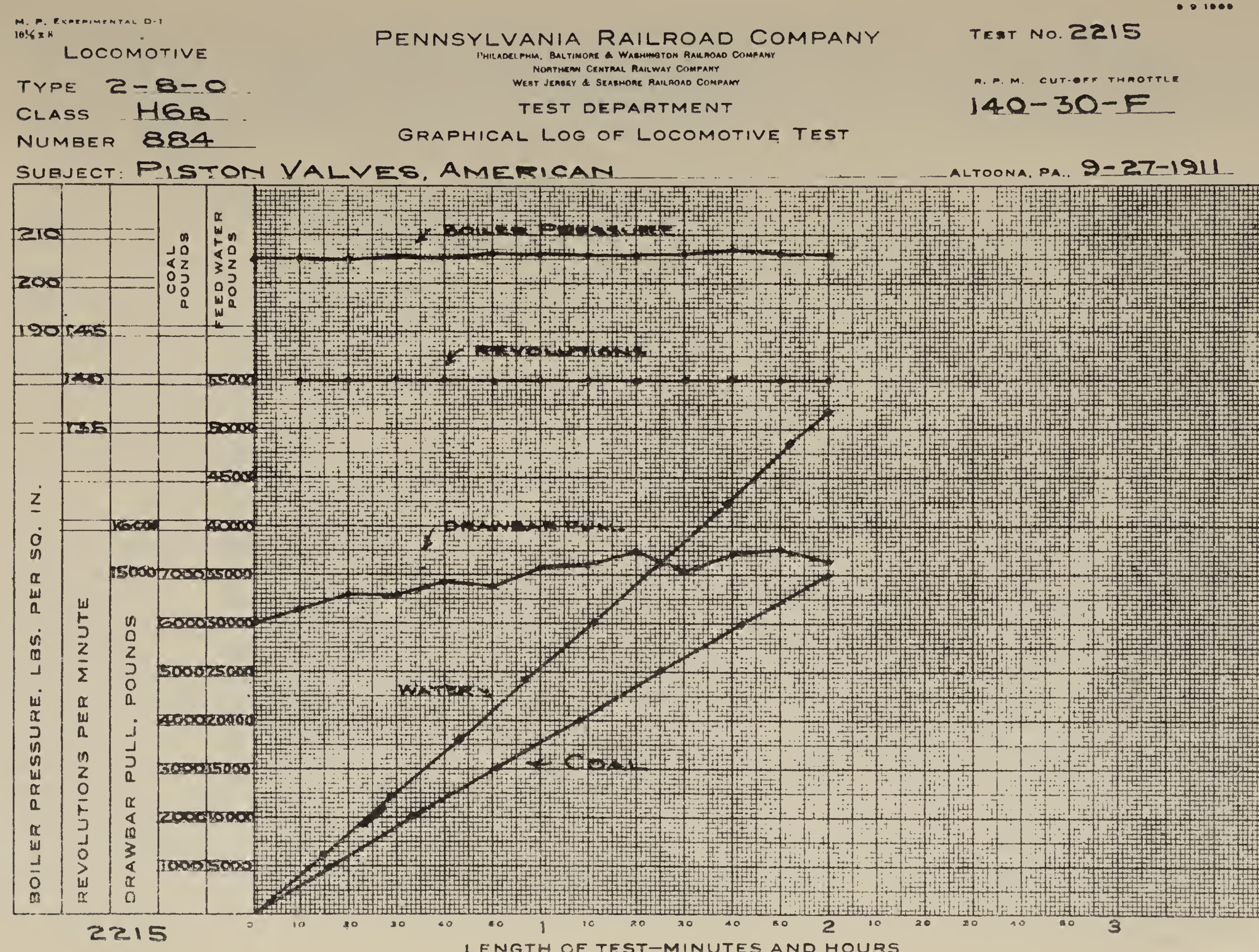
Altoona, Pa., 9-25-1911



2212


PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2213
100-40-F
R.P.M. CUT-OFF THROTTLE
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT: PISTON VALVES, AMERICAN
ALTOONA, PA., 9-26-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
REVOLUTIONS
DRAWBAR PULL
COAL
LENGTH OF TEST—MINUTES AND HOURS
2213


PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 2214
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 884
SUBJECT PISTON VALVES, AMERICAN
R. P. M. CUT-OFF THROTTLE
120-40-F
ALTOONA, PA. 9-26-1911
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
LENGTH OF TEST—MINUTES AND HOURS
2214


M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 884
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 2215
R. P. M. Cut-off Throttle
140-30-F
Subject: Piston Valves, American
Altoona, Pa., 9-27-1911
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
210
200
190
145
140
135
16000
15000
55000
50000
45000
40000
7000 35000
6000 30000
5000 25000
4000 20000
3000 15000
2000 10000
1000 5000
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
2215
0 10 20 30 40 50 1 10 20 30 40 50 2 10 20 30 40 50 3
Length of Test—Minutes and Hours

M. P. Experimental D 1
LOCOMOTIVE

TYPE 2-8-0
CLASS H6B
NUMBER 884

PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

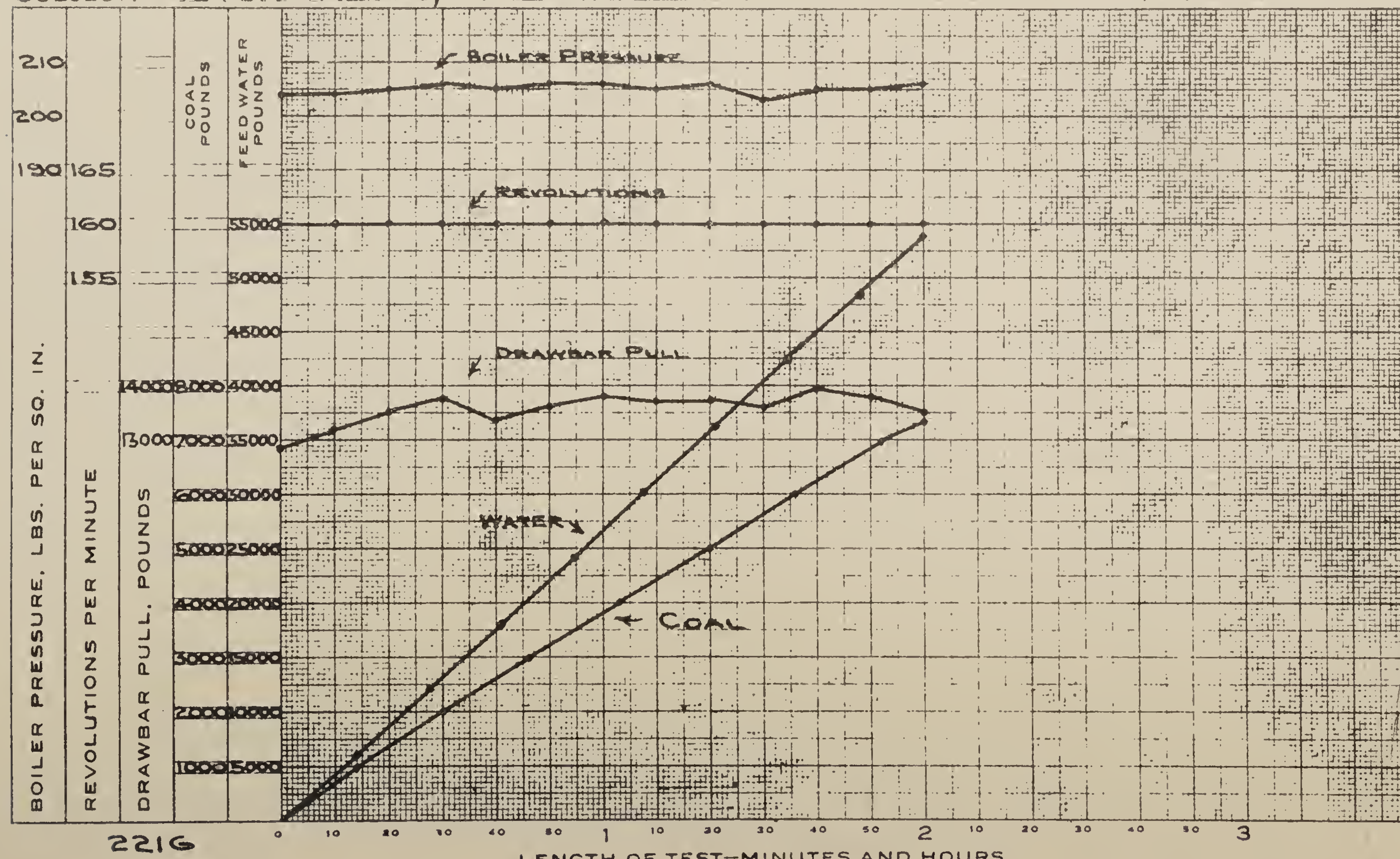
GRAPHICAL LOG OF LOCOMOTIVE TEST

TEST No. 2216

R. P. M. CUT-OFF THROTTLE
160-30-F

SUBJECT: PISTON VALVES, AMERICAN

ALTOONA, PA., 9-27-1911



PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 8 (Revised)

Formerly Bulletins Nos. 10 and 23

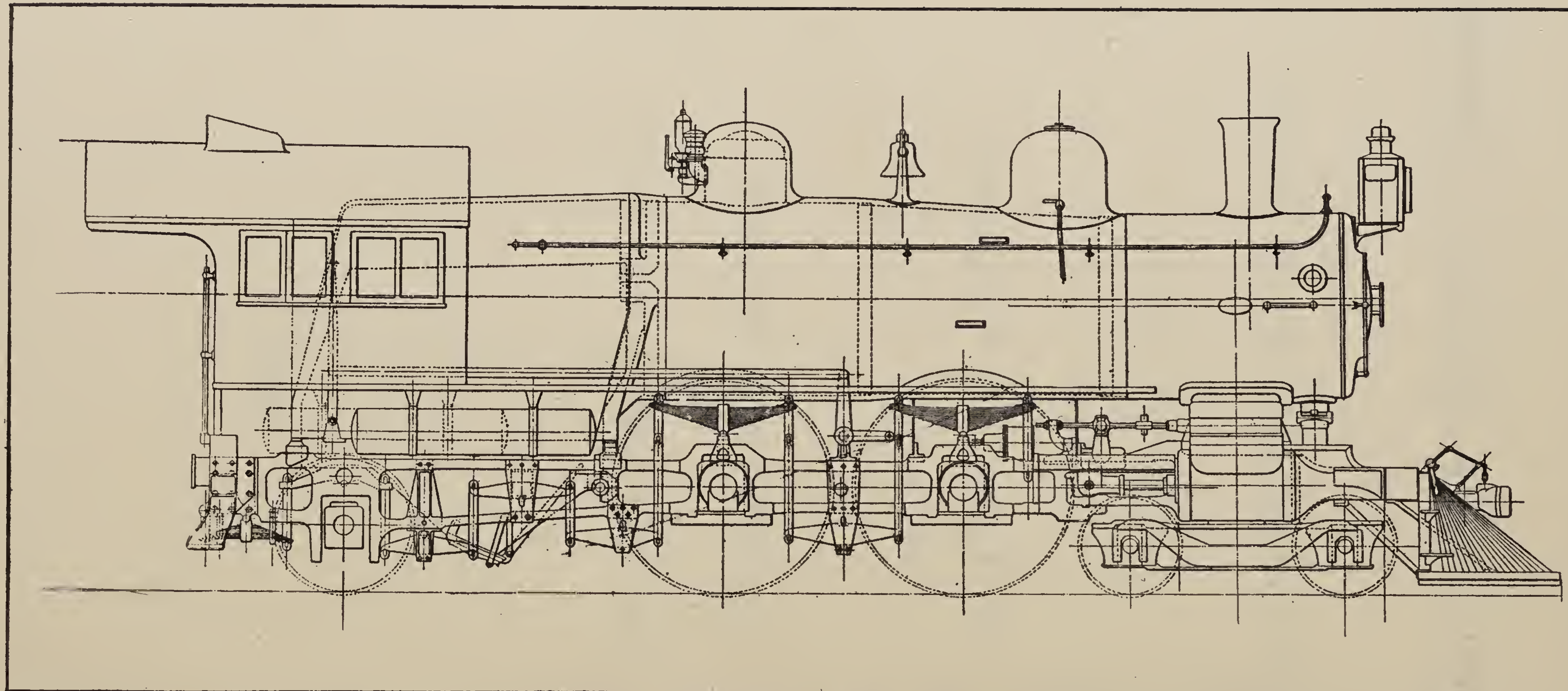
GRATE AREA REDUCED

AND

GRATES WITH SOLID ENDS

Copyright, 1912, by Pennsylvania Railroad Company

1912



GENERAL ARRANGEMENT OF LOCOMOTIVE.
Fig. 1.

LOCOMOTIVE TESTING PLANT.

GRATE AREA REDUCED.

Two forms of modified grate tested for their influence upon boiler efficiency and smoke.

(Conclusions and recommendations on pages 26 and 29.)

INTRODUCTION.

1. These tests justify the conclusion that a reduction in the grate area is undesirable and that such a practice affects the boiler capacity and efficiency and does not improve the smoke conditions. Efforts to abate smoke on a locomotive should be directed along other lines than by the blocking off of existing grate areas.

2. In view of the introduction of mechanical stokers, the subject deserves more careful study, and it is hoped that the following description of tests of different areas of grate will add something of value to the data on this subject.

3. Before the general use of the wide grate on locomotives, the length had been limited to about ten feet, as the greatest distance that coal could be thrown by the average fireman and with the introduction of the wide grate the length has still been restricted for the same reason.

4. There seems to be an impression on certain divisions that the wide grate is too large on some of our passenger locomotives, for best results, and extensive use has been made of a method of blocking off or covering part of the grate surface, usually at the forward end. The assertions in regard to this or any other method of reducing the grate area were debatable. On long passenger runs it has been claimed that the grate, thus reduced in area, is easier to fire because of its being smaller and the active part near the firedoor so that coal does not have to be thrown so far to cover it.

5. Whether or not the reduced grate is easier for the fireman to handle will probably remain a matter of individual opinion and one not easily determined for the average fireman. There are, however, certain facts in regard to the reduced grate that can be developed by tests, and the tests hereafter described have been made to show the effect of the reduced grate, in coal consumption and emission of smoke. The practice of reducing the grate is found to be undesirable as the capacity of the locomotive for making steam is reduced and little benefit in smoke reduction realized.

6. The standard grate for the class E2a locomotive has an area of 55.5 square feet, including the dead grate at the forward end, which has an area of about 9 square feet. There are two drop grates which are fixed, but have holes for the admission of air. The active or shaking portion of the grate has an area of about 31 square feet.

Method of Reducing Grate Area.

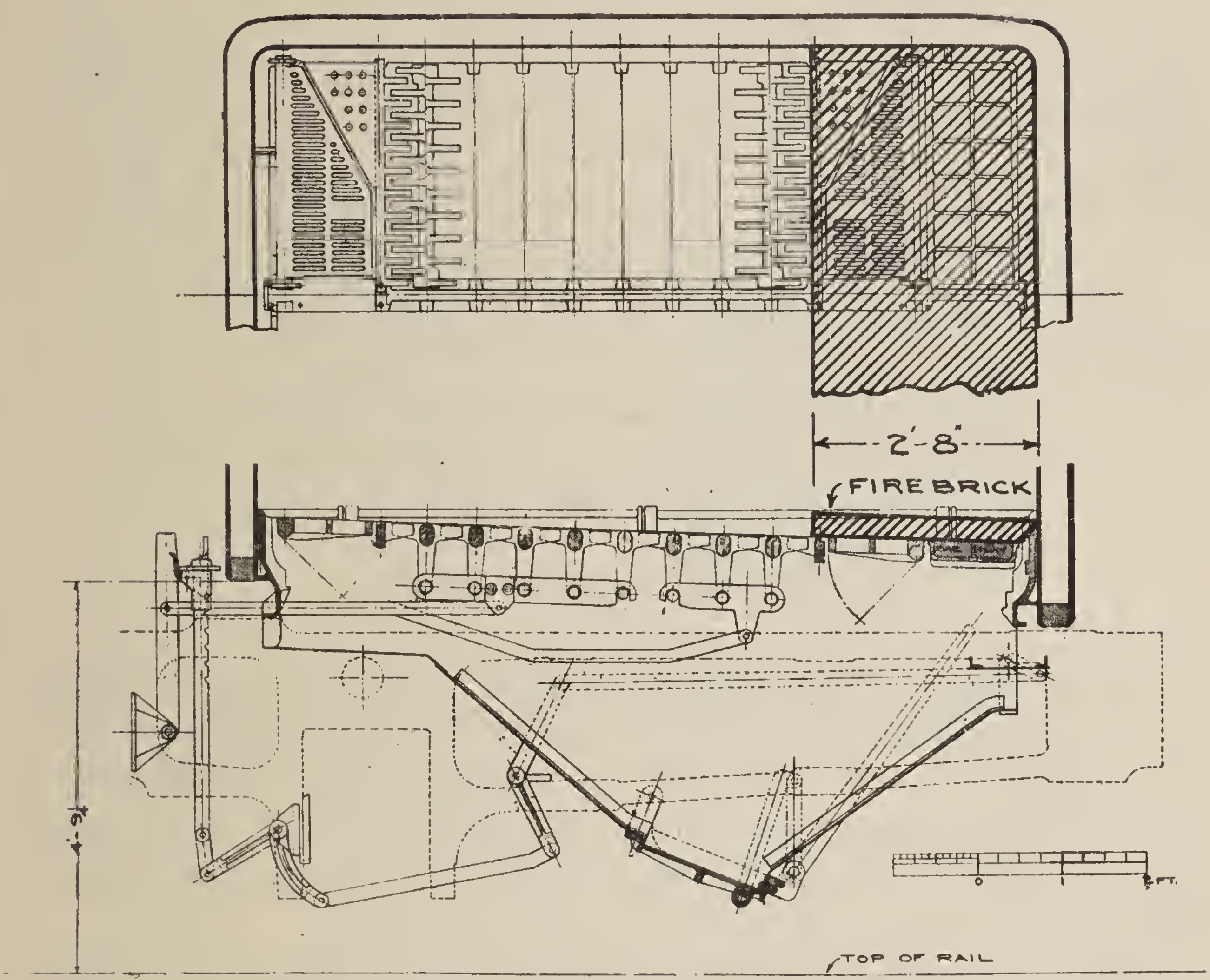
7. On the Atlantic City Division where the grate has been reduced, the method used is to disconnect six sections of shaking grate at the front end of the firebox. This portion of the grate is then covered with firebrick. Sometimes a sheet of steel is placed over the grate before laying the bricks so that there will be no cold air leaks, should any of the bricks become broken.

8. On the New Jersey Division a similar method is used but the area covered with brick is less, so that all of the shaking part of the grate is still open and can be operated.

9. The areas of the several grates are given below.

	Area of Grate in Sq. Feet.	Relative Area in Percent.	Ratio of Heating Surface to Grate Area.
Standard	55.5	100	41.8
New Jersey Division	39.5	71	58.7
Atlantic City Division	29.76	54	77.9

10. The grate of this locomotive as reduced in area on the New Jersey Division is shown in Fig. 2, while Fig. 3 shows the method used on the Atlantic City Division.



GRATE WITH FRONT PORTION COVERED WITH FIREBRICK
as used on New Jersey Division. All of the shaking grates can be used. The grate area is reduced 29%.
Fig. 2.

11. The locomotive used in the tests was an Atlantic Type passenger locomotive of the E2a class and is shown in Fig. 1.

Coal Used in the Tests.

12. Two kinds of coal were tried, one a low volatile coal, which breaks up easily into small particles and is drawn through the tubes in the form of cinders and sparks, and the other a

Pittsburgh region gas coal, which shows little tendency to disintegrate in the firebox. The analysis of the two coals was as follows:

	Scalp Level Coal	Penn Gas Coal
Fixed carbon	76.98%	58.35%
Volatile combustible	15.96	35.65
Ash	6.02	4.71
Moisture	1.04	1.29
	100.00	100.00
Sulphur	0.91	1.15
B. t. u. per pound, dry	15167	14864

Method of Making Tests.

13. The tests were of two or three hours duration in most cases. The locomotive was run under the test conditions for about fifteen minutes before the test began. The fire would then have been built up and the rate of firing established for the load upon the boiler. The firing was continued at the same rate of firing as shown by the graphical log for each test.

14. The boiler was operated under light, medium, and heavy loads and the firing was done by experienced men.

Results of Tests.

Low Volatile Coal, Evaporation:

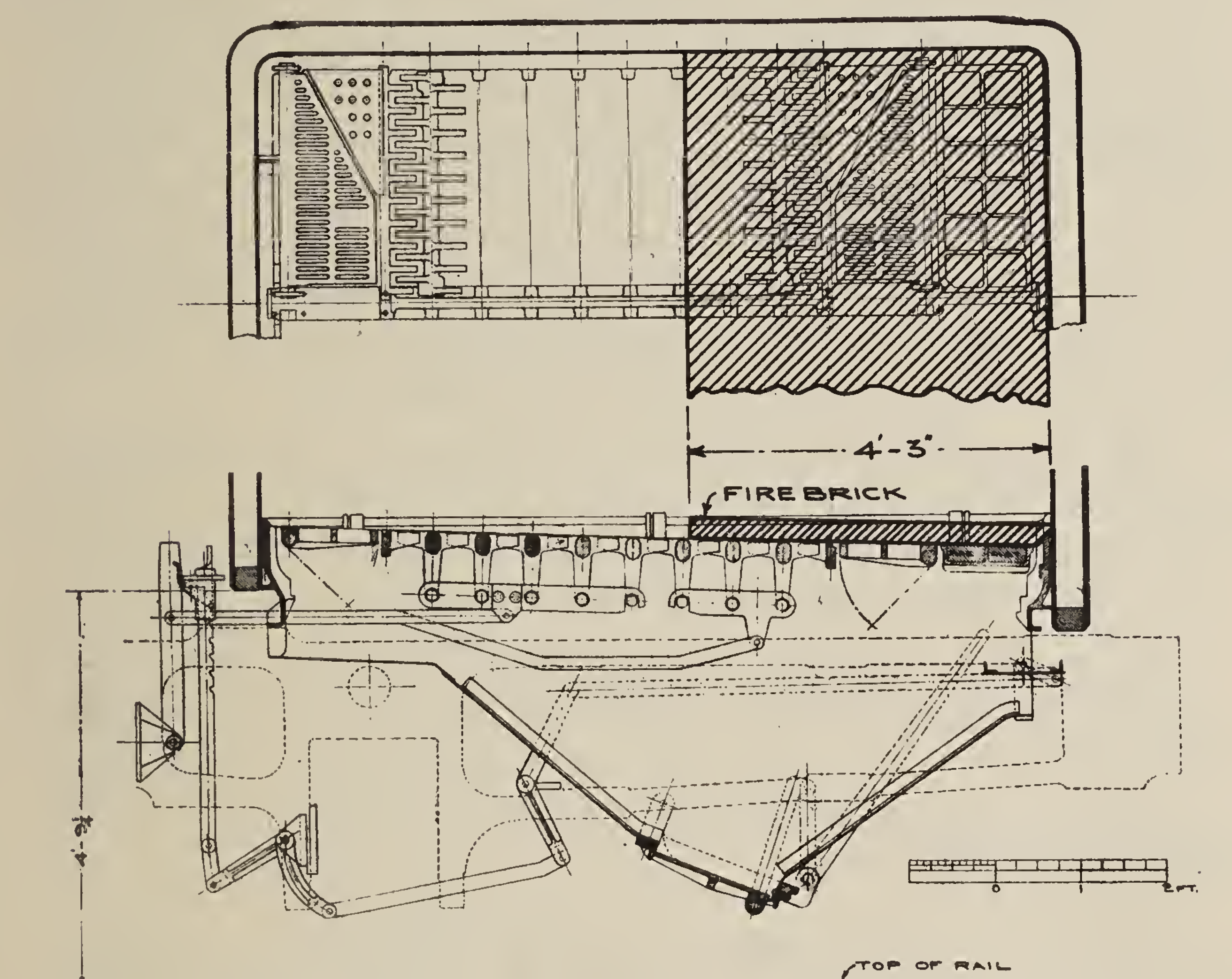
15. The results of the tests with the low volatile coal on two sizes of grate are shown on Tables 4 and 6 and some of these results, showing the evaporation and efficiency, are plotted in Figs. 4, 5 and 6.

16. With the reduced grate there is a loss in evaporation and efficiency through the whole range of out-put of the boiler; the

greatest loss being shown at the lower rates of evaporation.

17. When the boiler is evaporating water at the rate of about 14 pounds per square foot of heating surface, the loss in coal due to the use of the small grate is about 29.4 per cent.

18. With the small grate the boiler could be forced to an evaporation of about 14 pounds per square foot of heating surface, while with the full size grate in use the evaporation was 16 pounds per square foot of heating surface, or an increase of 14.3 per cent. The small grate then limits the steaming capacity of the boiler.



GRATE WITH FRONT PORTION COVERED WITH FIREBRICK
as used on Atlantic City Division. Six grate bars are inoperative. The grate area is reduced 46%.
Fig. 3.

19. The use of the low volatile coal, such as was tried in this test, is not present practice on passenger locomotives, and the tests show very clearly that this small grate is not at all suitable for this class of coal.

Cinders and Sparks:

20. The immediate effect of a reduction in grate area with low volatile coal is to cause more cinders and sparks to be drawn through the tubes, for the reason that, as the area of the grate becomes smaller, the draft, through what is left, becomes more intense and as a consequence the particles of coal are carried along with the gases in increasing quantities. These unburned cinders and sparks are almost entirely clean coke, and would, if burned, release about ten or eleven thousand heat units per pound. They escape unburned, however, and the heat that they contain is lost. The disadvantage of increasing the spark and cinder losses is thus apparent, because it means a loss of heat that might be made available for evaporation.

21. An indication of the extent of the losses from the cinders and sparks is given in Table 1 where the calorific value of the coal is compared with that of the cinders collected in the smoke-box and the sparks discharged from the stack.

22. With low volatile coal the cinders collected in the smoke-box were at times as much as 900 pounds per hour, with the full grate, and it is evident that even the full grate is not large enough, and only allows this coal to be burned with serious cinder and spark losses.

23. The weight of the sparks thrown out of the stack was not observed, as a satisfactory method for catching them had not yet been provided at the time of the tests. These sparks are large in amount, however, and their discharge from the stack is undesirable as in the course of time they fill the stone ballast of the track and choke the drainage making it necessary to frequently fork the ballast in order to keep the road bed in proper condition.

High Volatile Coal, Evaporation:

24. Following those already described, another series of

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Bulletin No. 8
TEST NOS., 950 to 953.
901,908,916,917,918.

SUBJECT: Grate Area Reduced.

ALTOONA, PA., 8-10-1907

No.	Item	Value
	DRIVING WHEELS	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	ENGINE TRUCK WHEELS	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS	
16	Diameter, inches	50
	WHEEL BASE, FEET	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels, in.	56.13
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	37167
21	" 1st Drivers	53334
22	" 2d "	56667
23	" 3d "	—
24	" 4th "	—
25	" 5th "	—
26	" Trailers	37000
27	Total	184167
28	" on Drivers	110000
	CYLINDERS	
	Diam. and Stroke, H. P	20.5 x 26
	" " " L. P	—
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.7
41	" " Crank "	12.1
42	" Left, Head "	12.4
43	" " Crank "	11.9
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	RECEIVER, CUBIC FEET	
48	Volume Right Side	—
49	" Left "	—
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	19.87
51	" " Width	1.48
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	19.84
67	" " Width	2.98
70	L. P. " Length	—
71	" " Width	—

No.	Item	Value
	PISTON RODS, DIAMETER INCHES	
74	High Pressure	3.472
76	Low "	—
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	—
80	Low "	—
	VALVES slide	
82	Type	Double Ported Bal.
83	Design	Amer. Bal. Valve Co.
84	Per Cent. Balanced	75.7
85	Type of Valve Motion	Stephenson
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	7.0
88	Low " "	—
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	1.5
94	Low " "	—
	INSIDE LAP OF VALVE	
98	High Pressure, inches	Neg. 0.16
102	Low " "	—
	BOILER	
113	Type	Belpaire, wide firebox
114	Outside Diam. 1st Ring	67
	TUBES	
115	Number	315
116	Outside Diam., inches	2
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	FIREBOX, INSIDE, INCHES	
132	Length	114
133	Width	68
137	Air Inlets to Ashpan, sq. ft.	6.3
	GRATES	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

No.	Item	Value
	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, "	156.86
157	" " Superh'r, "	—
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	338.6
161	Steam " " "	109.9
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.625
167	Area, sq. inches	24.85
	REVERSE LEVER	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	—
	RATIOS Full Grate	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	0.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

Ratios, Reduced Grate.

	Grate area	39.5	29.76
171	---------	58.71	77.93
172	---------	0.13	0.18
173	---------	3.97	5.27

*USED IN CALCULATIONS

DIMENSIONS OF E2a CLASS LOCOMOTIVE 5266.
The locomotive used for the Reduced Grate tests.
Table 3.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY Bulletin No. 8

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

950 to 953
FUEL: Penn Gas.
901 to 917
Scalp Level

SUBJECT: Full Grate, 55.5 sq. ft.

ALTOONA, PA., 8-10-07

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Coal	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
950	80-15-F	3.00	19.10	Full		Penn	204.5	2.0	.1	14713	125
951	120-20-F	3.00	28.42	"		Gas	201.4	3.4	.2	14864	49
952	160-25-F	2.50	38.02	"		"	201.9	3.8	.2	14864	48
953	160-32-F	2.00	38.02	"		"	198.9	7.3	.3	14864	91
901	80-15-F	3.00	19.10	"		Scalp	201.3	2.0	.2	15264	52
908	120-20-F	3.00	28.65	"		Level	201.0	5.9	.7	15167	101
916	160-25-F	2.50	38.20	"		"	200.0	5.2	.3	15264	302
917	160-27-F	3.00	38.20	"		"	188.4	7.7	.3	15167	492
918	160-30-F	1.00	38.20	"		"	186.1	8.9	1.3	15167	987

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Fire-box.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
950	1808	32.58	14647	17798	7.67	9.84	515.9	64.59	0.5		
951	2585	46.58	20652	25235	10.88	9.76	731.4	63.42	0.8		
952	3768	67.89	27598	33764	14.56	8.96	978.7	58.22	1.2		
953	5480	98.74	35144	43030	18.56	7.85	1247.3	51.01	2.1		
901	1665	30.00	14673	17806	7.68	10.69	516.0	67.65	0.6	198.3	
908	2455	44.24	20135	24434	10.54	9.95	708.2	63.36	1.7	197.7	
916	4221	76.05	26436	32246	13.90	7.64	934.7	48.34	1.5	195.0	
917	4802	86.53	28670	34793	15.00	7.25	1008.5	46.17	2.1	185.6	
918	5581	100.58	30721	37170	16.03	6.66	1077.4	42.41	3.0	181.8	

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O Smoke-box gases	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Percent
	214	379	380	381		265	383	384	385	398	399	
950	14172				0	7059	359.6	5.03	39.42		3.44	72
951	20448				0	7579	574.3	4.50	35.58		3.80	38
952	27326				.27	8768	888.9	4.24	30.74		4.04	46
953	34800				.67	11790	1195.3	4.58	29.11		3.74	52
901	14077	419.8	3.97	33.54	0	6427	327.3	5.09	43.02		3.28	No
908	19548	687.6	3.57	28.81	0	7280	556.2	4.42	35.16		3.79	Record
916	25529	1011.6	4.17	25.22	0.06	8155	830.7	5.08	30.73		3.28	
917	27958	1055.0	4.55	26.50	0.60	8757	892.1	5.38	31.34		3.18	
918	30057	1133.4	4.92	26.46	0.60	9571	975.0	5.72	30.83		2.95	

TESTS WITH THE WHOLE GRATE IN USE.

Two coals were used, Penn Gas and Scalp Level. The first a high, and the second a low volatile coal.

Tablo 4.

M. P. 854 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Bulletin No. 8
FUEL: Penn Gas
Coal

SUBJECT: Grate Area Reduced to 39.5 sq. ft.

ALTOONA, PA., 8-10-07

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Coal	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
905	80-15-F	3.00	19.01	Full		Penn	200.7	2.2	.1	14411	26
925	120-20-F	3.00	28.42	"		Gas	204.9	3.5	.3	14411	31
926	160-25-F	2.50	37.78	"			203.1	4.7	.3	14411	81
928	160-32-F	2.00	37.78	"			201.5	7.5	.3	14411	120

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Fire-box.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	346	347	349	350		220	230
905	1802	45.62	15083	18483	7.97	10.26	535.7	68.76	0.5		
925	25.36	64.20	20097	24395	10.52	9.62	707.1	64.47	1.3		
926	3952	100.05	26558	32285	13.92	8.17	935.8	54.75	1.5		
928	5389	136.43	34350	41802	18.02	7.76	1211.7	52.01	2.7		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O in Smoke-box gases.	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Percent
	214	379	380	381		265	383	384	385	398	399	
905					0	7454	377.8	4.77	39.48		3.70	18
925					0.07	8072	613.7	4.13	32.40		4.28	24
926					0	9561	963.3	4.10	27.18		4.31	36
928					0.4	11980	1207.0	4.46	28.15		3.96	52

TESTS WITH THE GRATE REDUCED
as in Fig. 2, and using a high volatile coal.
Table 5.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No. 8

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

945 to 948
FUEL: Penn Gas
940 to 944
Scalp Level

SUBJECT: Grate Area Reduced to 29.76 sq. ft.

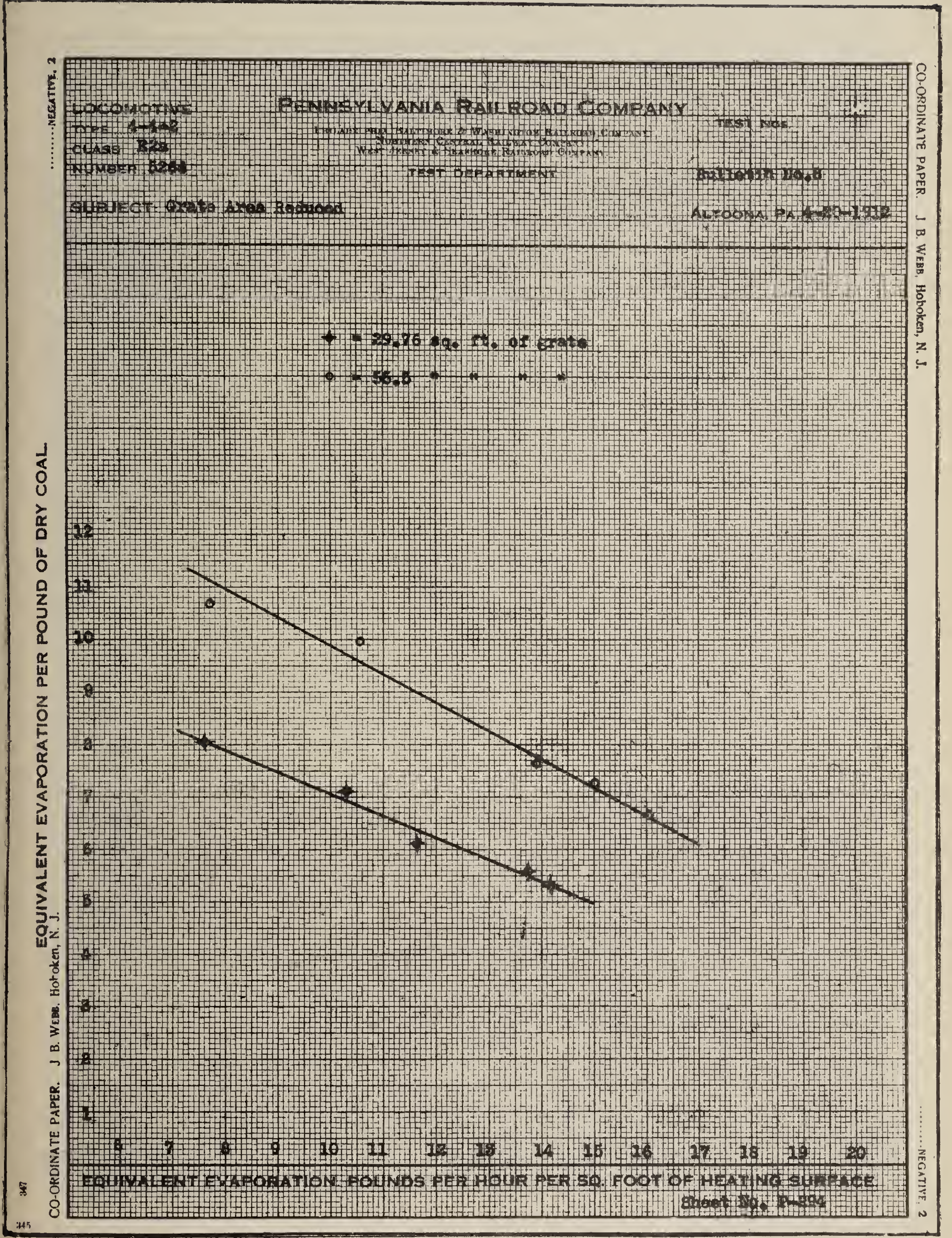
ALTOONA, PA., 8-10-07

TEST NUMBER	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Coal	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	RUNNING CONDITIONS						BOILER PERFORMANCE				
	R. P. M. Cut-off Throttle	198	199	203	268 to 271		217	222	225	248	288
946	80-30-F	3.00	19.10	6 1-2 notches	27.5	Penn	195.1	1.5	.0	14713	30
948	120-20-F	3.00	28.65	Full	18.4	Gas	202.1	3.5	.2	14713	42
945	160-25-F	2.50	38.20	"	23.8	"	200.4	5.5	.2	14713	93
947	160-32-F	2.00	38.20	"	32.9	"	182.6	7.2	.2	14713	128
940	80-15-F	3.00	19.10	"	14.5	Scalp	199.1	2.3	.1	15077	104
941	120-20-F	3.00	28.65	"	18.2	Level	196.9	3.5	.1	15077	324
943	80-30-F	2.50	19.10	"	29.9	"	202.7	3.9	.1	15077	327
942	160-25-F	1.33	38.20	"	24.3	"	195.1	5.7	.2	15077	888
944	160-25-F	1.67	38.20	"	24.0	"	187.8	6.1	.1	15077	775

TEST NUMBER	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Fire-box.	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	338	339	340	344	345	347	349	350		220	230
946	1246	41.87	11677	14178	6.11	11.38	411.0	74.70	0.6	96.3	
948	2345	78.80	20289	24812	10.70	10.58	719.2	69.45	1.3	199.3	
945	3772	126.75	26483	32820	14.15	8.70	951.3	57.11	2.7	195.8	
947	5014	168.48	33067	40426	17.43	8.06	1171.7	52.91	3.0	179.5	
940	2195	73.76	14527	17652	7.61	8.04	511.7	51.50	0.9	196.2	
941	3366	113.10	19613	23936	10.32	7.11	693.7	45.54	1.3	193.8	
943	4406	148.05	22050	26932	11.61	6.11	780.6	39.14	1.4	199.0	
942	6177	207.56	26917	32846	14.16	5.32	952.1	34.08	1.8	191.8	
944	5753	193.31	26080	31858	13.74	5.54	923.4	35.49	1.9	184.9	

TEST NUMBER	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O Smoke-box gases.	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Percent
	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	214	379	380	381		285	383	384	385	398	399	
946	11234	307.3	4.05	36.57	0	5084	259.0	4.81	43.39	84.28	3.60	2
948	19684	706.4	3.32	27.87	0	7336	560.5	4.18	35.13	79.35	4.14	22
945	26388	1031.8	3.66	25.58	0.3	8360	851.6	4.43	30.99	82.54	3.90	No record
947	32408	1232.4	4.07	26.30	0.7	9831	1001.5	5.10	32.97	81.26	3.39	38
940	13818	417.6	5.26	33.10	0	6712	341.9	6.42	40.43	81.67	2.63	No Record
941	18996	685.9	4.91	27.99	0	7092	541.9	6.21	35.42	79.01	2.72	
943	20889	720.0	6.12	29.30	0.47	12321	627.6	7.02	33.61	87.17	2.40	
942	26259	1019.3	6.06	25.95	0.60	8227	838.1	7.37	31.56	82.23	2.29	
944	25453	974.6	5.90	26.31	1.40	7795	792.1	7.24	32.29	81.48	2.33	

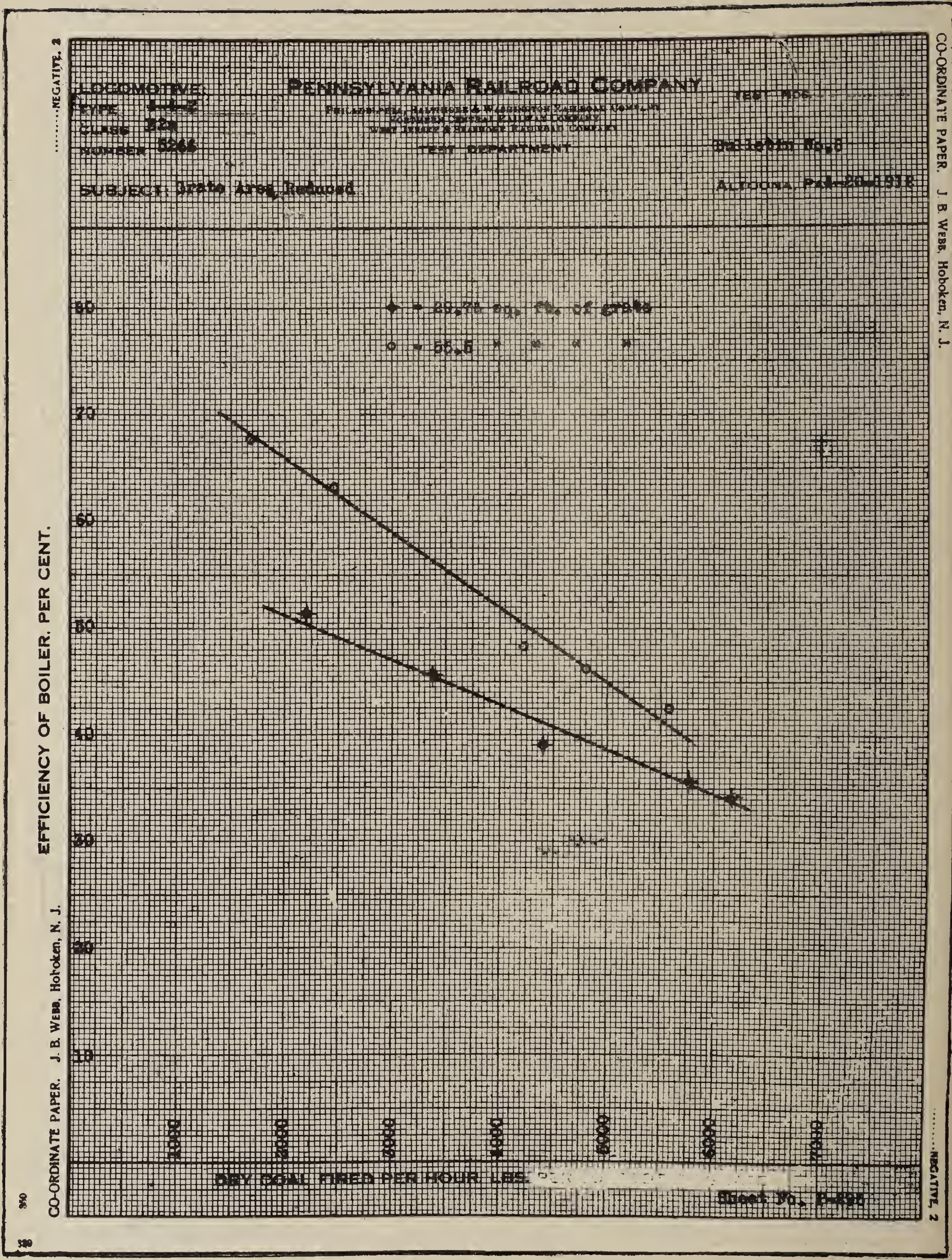
TESTS WITH THE GRATE REDUCED
as in Fig 3, and using both a high and low volatile coal.
Table 6.



EVAPORATION PER POUND OF COAL.

The upper line is for the full grate and the lower line, showing much less water per pound of coal, is for the grate blocked off to the smallest area. The coal used was Scalp Level, a low volatile light friable coal.

Fig. 4.



EFFICIENCY OF BOILER.
The large grate as shown by the upper line gives the best results. The coal has been plotted in total pounds per hour instead of per square foot of grate, because there were two sizes of grate. The coal used was Scalp Level.
Fig. 5.

tests was run on three sizes of grates to show the effect of changes in the grate area when using Penn Gas coal, which is

TABLE 1.

Test No.	Calorific Value, B. t. u. Per Pound			Kind of Coal	Grate Area Sq. Ft.
	Of Dry Coal	Cinders	Sparks		
901	15264	11713	10868	Scalp Level	55.5
908	15167	10606	8484	"	"
916	15264	9287	9042	"	"
917	15167	9701	11617	"	"
918	15167	11497	10899	"	"
950	14713	10808	19028	Penn Gas	55.5
951	14864	10659	9540	"	"
952	14864	11430	11017	"	"
953	14864	11312	10370	"	"
905	14411	11109	11109	Penn Gas	39.5
925	14411	9008	9298	"	"
926	14411	10691	10572	"	"
928	14411	9971	10452	"	"
940	15077	10227	10227	Scalp Level	29.76
941	15077	10868	11997	"	"
943	15077	11291	12216	"	"
942	15077	11351	11977	"	"
944	15077	10660	11677	"	"
946	14713	8623	10300	Penn Gas	29.76
948	14713	10061	11672	"	"
945	14713	11198	11618	"	"
947	14713	10898	11018	"	"

high in volatile combustible and is representative of the kind of coal used on passenger locomotives. The grate areas chosen were those referred to in the first portion of this report, namely: full, 39.5 and 29.76 square feet. With this coal, the results obtained are very different from those with the low volatile coal. Figs. 7,

8 and 9 and Tables 4, 5 and 6 show the results with the high volatile coal. Unless the boiler is forced to high rates of evaporation, the evaporation per pound of coal and the efficiency of the boiler are not much influenced by the reduction in the grate.

25. It is noticeable, however, that the full size grate gives an equivalent evaporation of 18.56 pound per square foot of heating surface, as a maximum, while with each reduction in grate the evaporation is decreased. It is 18.02 with the medium grate and 17.43 with the small grate. The full grate is none too large for high volatile coal, and a reduction in it limits the output of the boiler.

Cinders:

26. In Fig. 9 the cinders caught in the smokebox are shown with the dry coal fired per hour. At all rates of firing the cinders are increased with the blocking off of the grate, showing again that the full size grate is none too large.

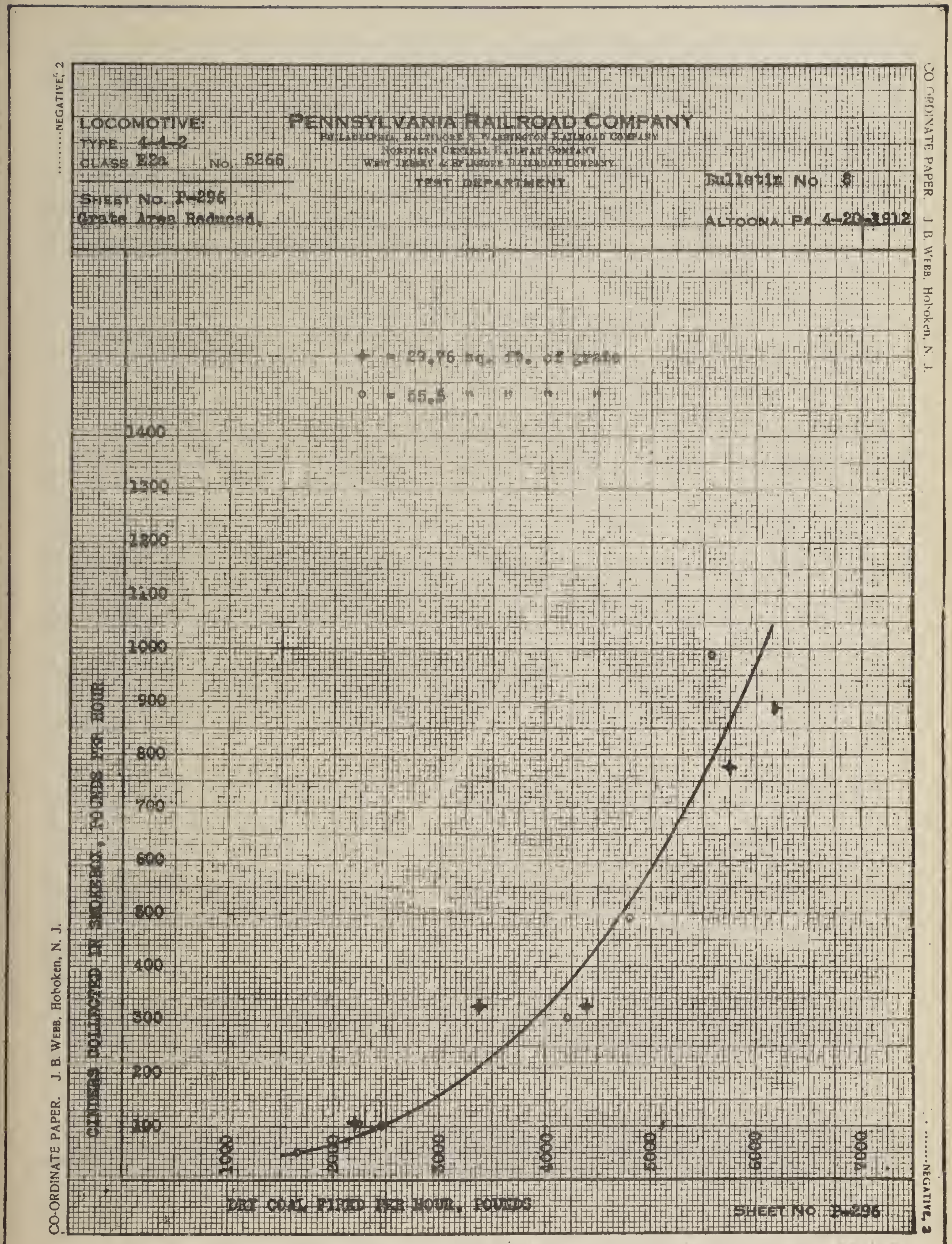
Smoke:

27. The smoke was observed during the trial with the high volatile coal with the results shown in Table 2.

TABLE 2.

Average Smoke (Ringelmann Scale) Penn Gas Coal.

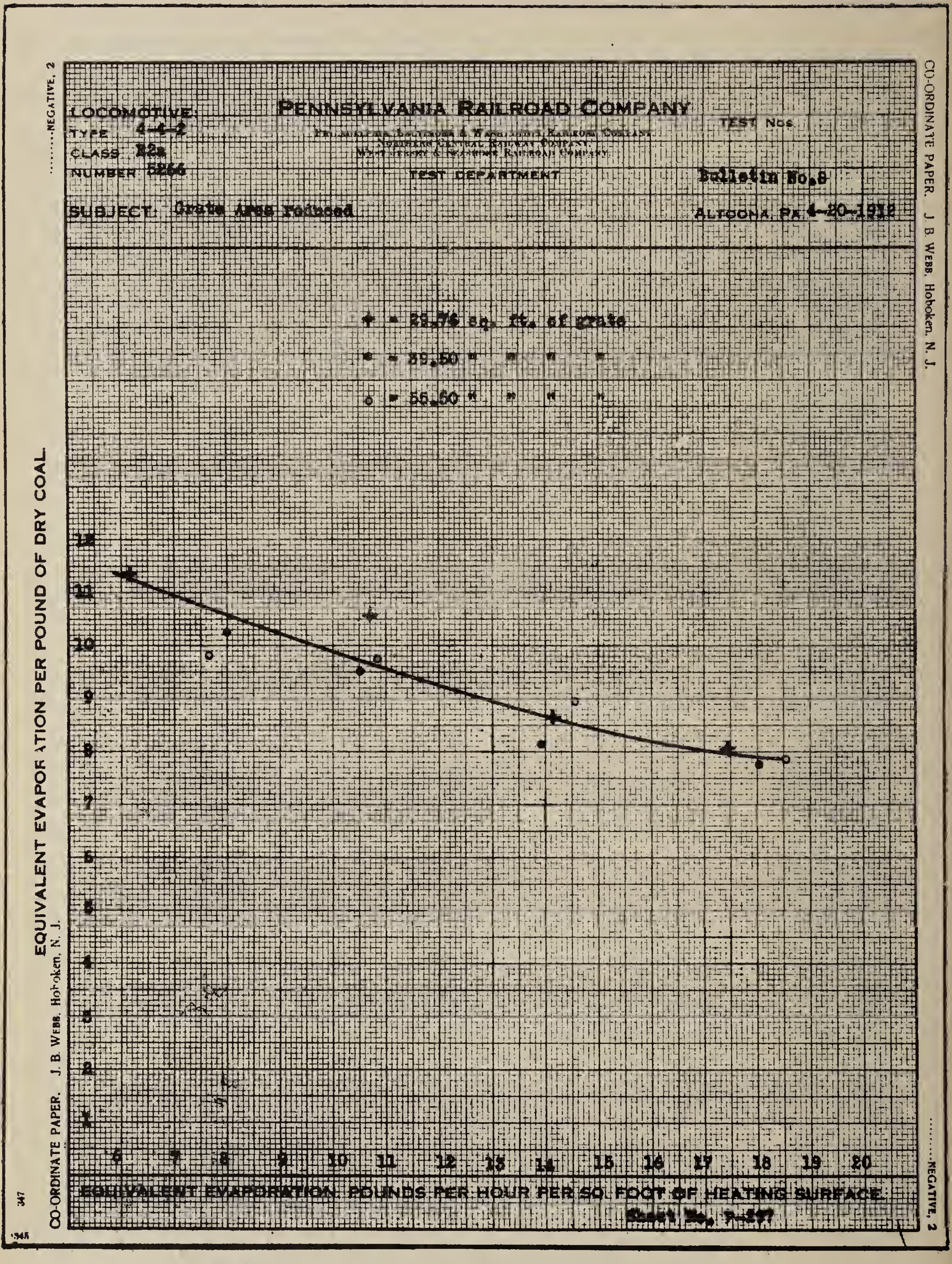
Test No.	Miles per Hour	Cut-Off	Throttle	Average Smoke in Per Cent	Analysis of Smoke-box Gases			Size of Grate
					Oxygen	C O	CO2	
950	19	15	Full	12	9.60	0	9.30	55.5sq.ft.
905	19	15	"	18	9.9	0	8.9	39.5 "
951	28	20	"	38	7.73	0	10.33	55.5 "
925	28	20	"	24	7.9	.07	10.3	39.5 "
948	28	20	"	22	7.33	0	11.0	29.76 "
952	38	25	"	46	7.07	.27	10.80	55.5 "
926	38	25	"	36	6.4	0	10.7	39.5 "
953	38	32	"	52	5.73	.67	11.13	55.5 "
928	38	32	"	52	4.4	.4	11.18	39.5 "
947	38	32	"	38	4.9	.70	11.9	29.76 "



CINDERS COLLECTED IN SMOKEBOX.

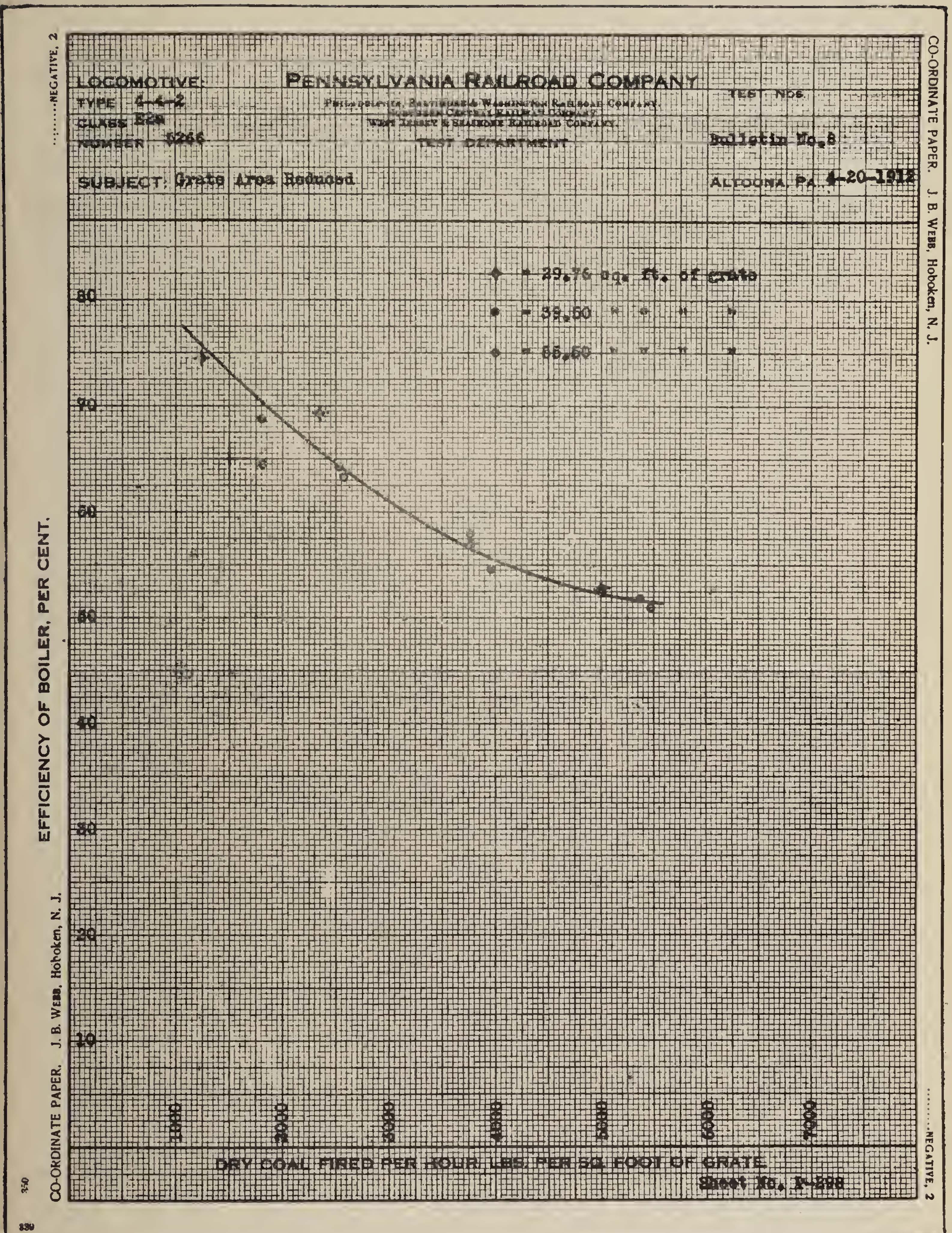
With this coal, Scalp Level, there is little difference between the two sizes of grate, in the quantity of cinders collected.

Fig. 6.



EVAPORATION PER POUND OF COAL, PENN GAS COAL.
With this coal the effect of the difference between the grates does not appear, except that the maximum evaporation is reduced with each reduction in grate area.

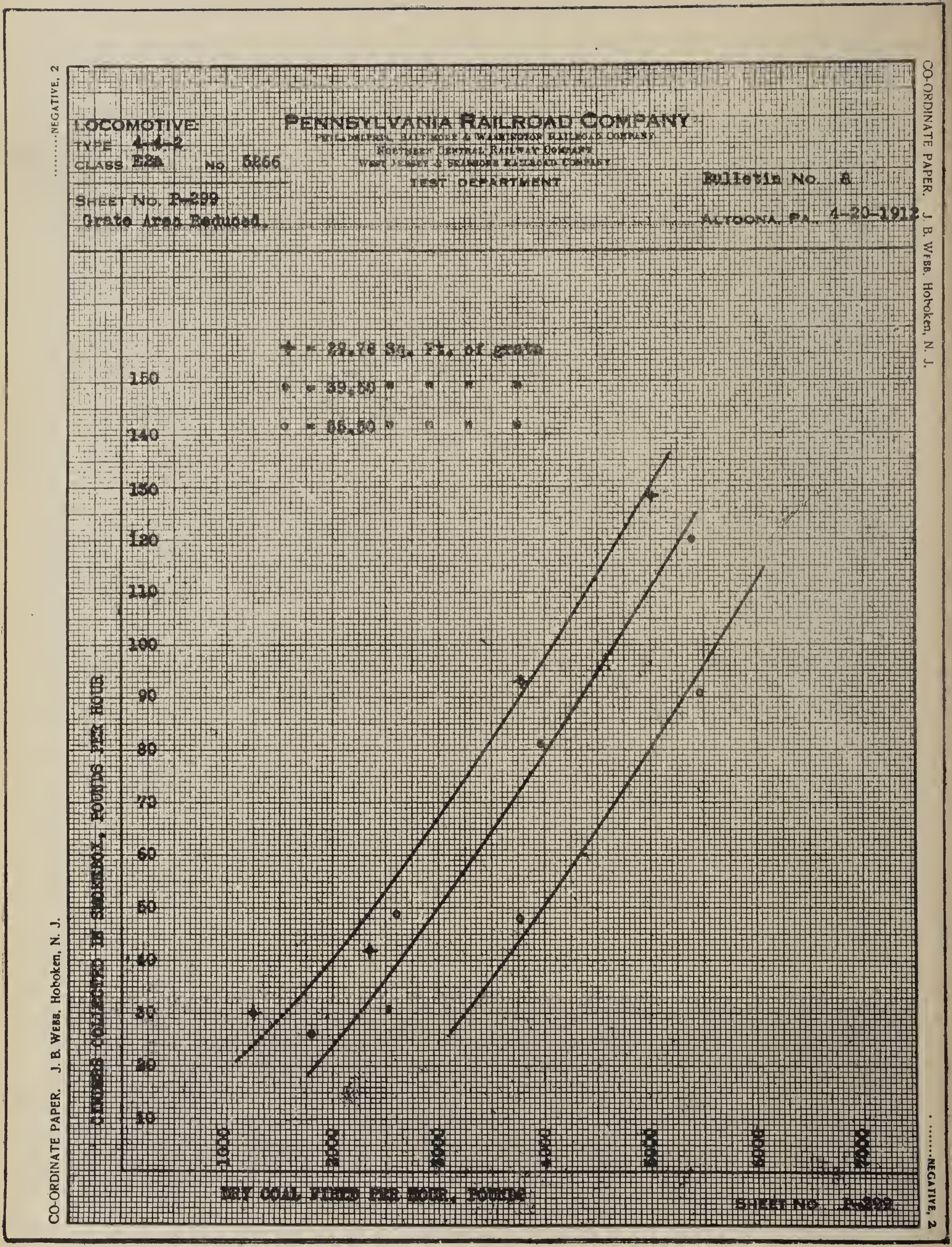
Fig. 7.



EFFICIENCY OF BOILER, PENN GAS COAL.

Three areas of grate.

Fig. 8.



CINDERS COLLECTED IN SMOKEBOX, PENN GAS COAL.

The effect of a reduction in grate surface is very clear on this diagram, and the large amount of cinders with the smaller grate indicates where the losses occur that limit the boiler capacity with the small grate.

Fig. 9.

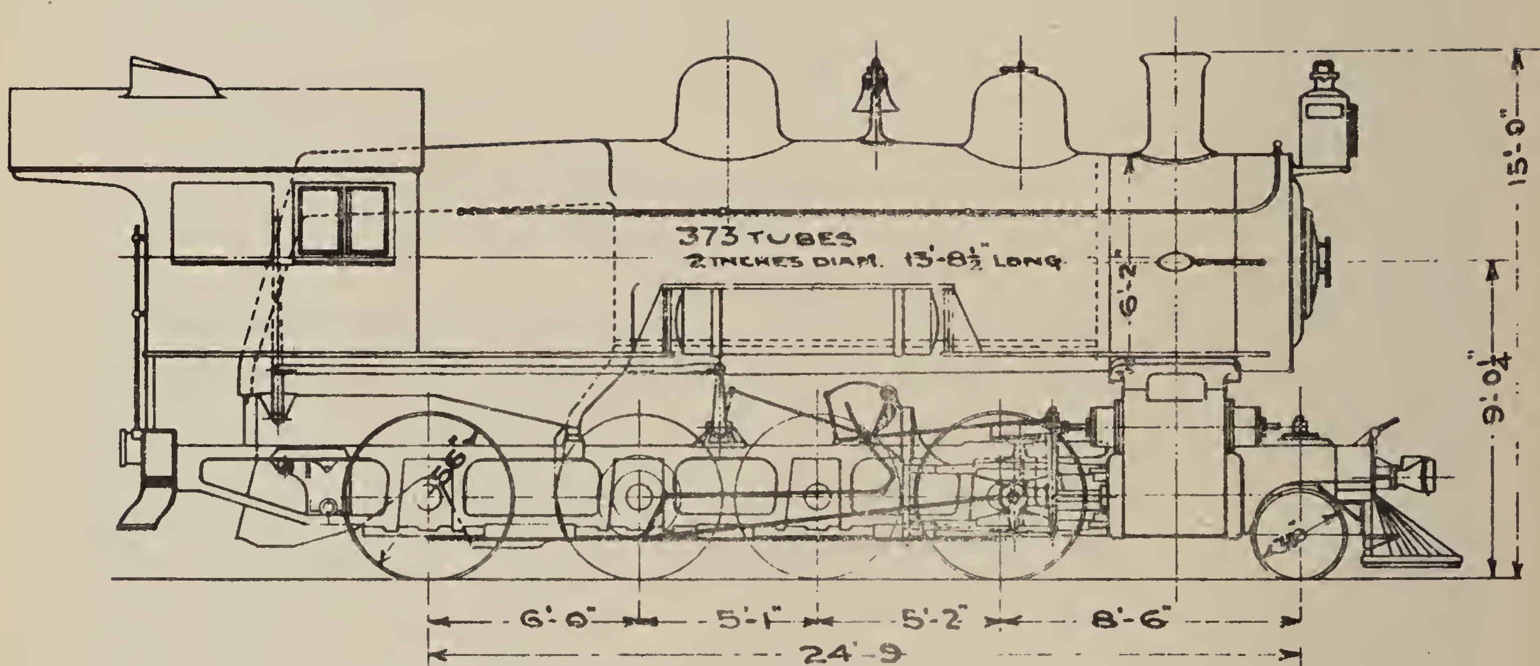
28. In general with this high volatile coal the smoke shown is less with the smaller grate than with the whole grate in use. The decrease in smoke is considerable with the smallest grate. There is a decrease of 27% in one case and 42% in the other.

29. The combustion on the small grate would appear from this to be better than the relatively slower combustion on the large grate, and this may be due to the combustion chamber that is formed at the front end of the grate over the blocked off portion.

30. The figures from the analysis of smokebox gases are too inconsistent to be used as the basis for any deductions in regard to combustion on the different grates.

31. After the tests on the E2a locomotive with the front end of the grate blocked off, a series of tests was made with a locomotive of the H6b class having the grate made solid around the edges.

32. As these tests are similar to the foregoing, in that part of the grate surface was blanked or blocked off, they will be described in what follows:



GENERAL ARRANGEMENT OF H6b CLASS LOCOMOTIVE.
Used in Solid End Grate tests.
Fig. 10.

GRATE WITH SOLID ENDS.

The second form of grate modification and results from its use.

INTRODUCTION.

33. For a long time past the Pennsylvania Railroad Company's locomotives have had grates with side bearing bars that fit close to the firebox sheets so that no air can enter the firebox between these bearers and the sheets. The sheets are thus protected, for a space of about 2 inches, from direct contact with cold air entering the furnace.

34. It has been proposed, in endeavoring to prevent smoke, that this protecting strip be widened and the air entering through the grate be compelled to come up at a greater distance from the firebox sheets, and tests of such an arrangement have been made. It was expected that this blocking of the grate would result in better combustion and evaporation and a reduction in the amount of smoke on account of the higher furnace temperature that would be possible. The results were not as anticipated, and no advantage was found in the use of the solid end grates. There was an increase in the smoke and no saving in coal from their use.

Description of Grate.

35. In order to test the effect of such a modification of the grate, a set of grates as shown in Figs. 11 and 12 were prepared for the H6b class locomotive. The photograph shows one section each of the front drop grate, half grate, filling piece and one section of the rocking or finger grate bar. The pieces shown, make up the forward end of the grate on one side of the firebox.

36. On the outside end, or the end of each grate bar nearest to the sheets, the openings through the grate have been closed up or the ends made solid. This solid part is about 6 inches wide, making a section of solid grate about 9 inches wide, if we include

the grate bearing bar, all the way around the firebox. The firebox sheets were thus protected more perfectly than is usual, and better combustion and less smoke was expected from this arrangement.

37. The total grate area, measured up to the firebox sheets is 48.66 square feet and the air openings through the grate with solid ends are a total of 15.41 square feet or 31.7 per cent of the grate area. The grate without the solid ends, or the standard grate for this locomotive, has air openings of 17.6 square feet or 36.4 per cent of the total grate surface.

The Tests.

38. Five tests of this grate were made and they were chosen so that they cover a wide range in evaporation. All of the tests were made with an H6b class locomotive, see Fig. 10. There were two speeds and cut-offs. For comparison with them, five other tests with this locomotive at similar speeds and cut-offs with the usual or standard grate have been selected.

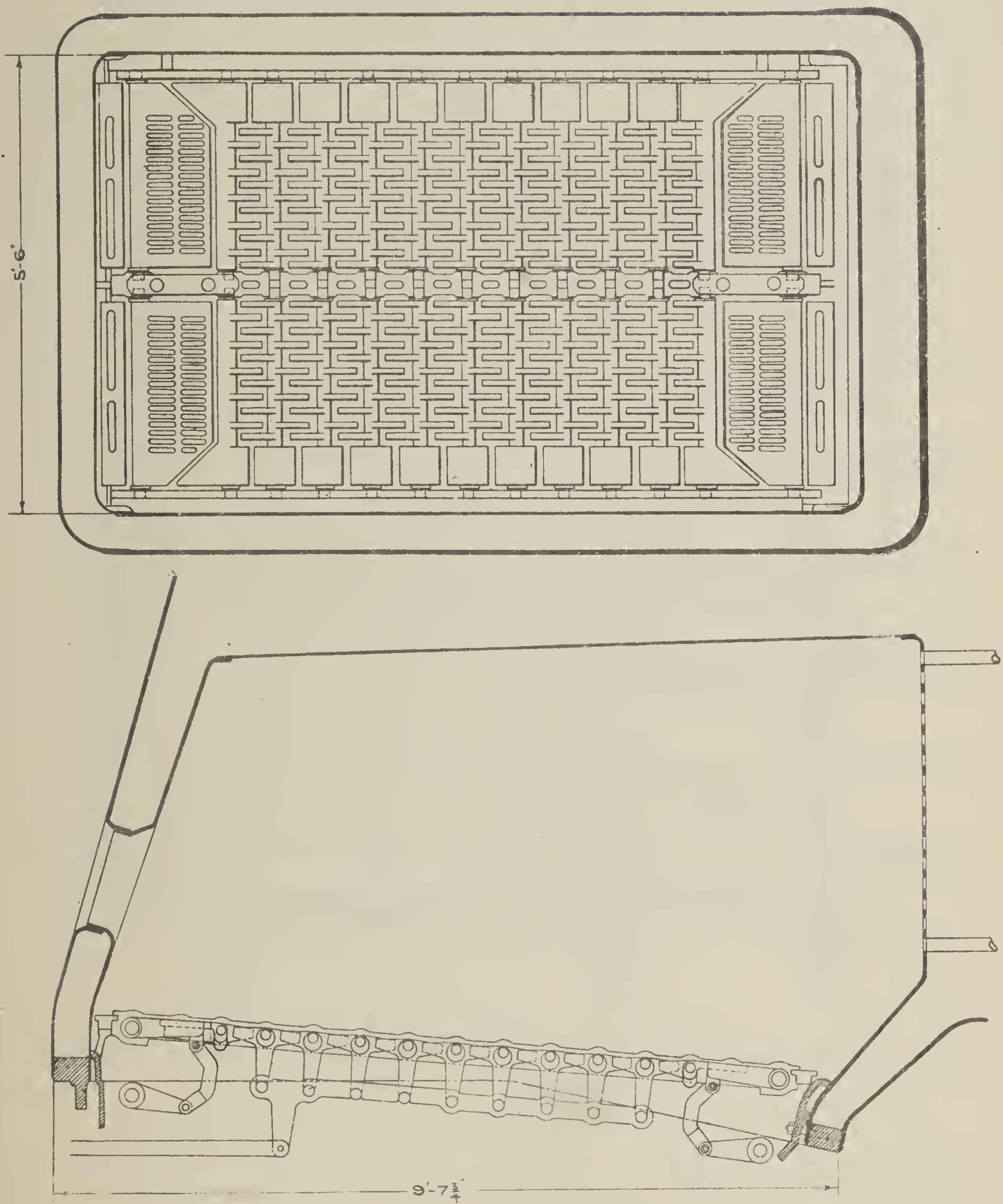
39. In all of the tests Jamison run-of-mine coal was used. The analysis of this coal is as follows:

Fixed Carbon	55.57
Volatile Combustible	31.59
Ash	11.95
Moisture	0.89
	100.00
Sulphur	2.21
B. t. u. per pound of dry coal	13540

The firing and handling of the locomotive were the same in all of the tests.

40. The results of the tests are shown on Table 9 and diagrams Figs. 13 to 16.

41. Table 7 showing observations of the smoke, would indicate that there is a trifle more smoke with the solid end grate than with the standard grate.



GRATE WITH SOLID ENDS.
As applied to H6b Class Locomotive.
Fig. 11.

TABLE 7.

Test Number		Test Designation			Average Smoke Number	
Standard Grate	Solid End Grate	M. P. H.	Cut-Off	Throttle	Standard Grate	Solid End Grate
1200.400	1200.405	12.86	20%	Full	12	14
1200.399	1200.406	12.86	30%	"	12	14
1200.401	1200.407	12.86	40%	"	12	16
1200.404	1200.408	19.3	40%	"	22	26
1200.410	1200.409	19.3	45%	"	32	30

This is further illustrated on the diagrams Figs. 13 and 14 which show the average smoke with coal fired and the average smoke with water evaporated.

42. On the diagram of evaporation per pound of coal and evaporation per square foot of heating surface (Fig. 15), no difference can be found between the two grates. The boiler capacity is apparently not limited to any great extent, by the use of this solid end grate.

Conclusions (Grate Area Reduced).

43. It has been demonstrated that with a light friable coal which easily forms cinders and sparks in large quantities, the blocking off of the grate has a very bad effect and there can be no justification for making the large grate smaller. If the low volatile coal is to be used in locomotives which are operated at rates close to their capacity, there should be provided a larger grate area than is now customary.

44. With the gas coal the conclusions are not so decidedly in favor of the full grate, for with this coal there is a little less smoke with the smaller grates, but at the same time there is a reduction in the capacity of the boiler to generate steam which is a much more serious limitation to the usefulness of the locomotive than is compensated for by the slight reduction in smoke. We must conclude, therefore, that the methods of blocking off the

GRATE BARS WITH SOLID ENDS.
Each of the different shapes, which make up the whole grate, are shown. There are four of the drop grate sections and 18 of the finger grates.
Fig 12.

grate, that were investigated, result in limiting the power of the locomotive, and the slight advantages shown in ease of firing and reduction of smoke would better be secured in some other manner by which the locomotive's power would be increased, rather than diminished.

Recommendations (Grate Area Reduced).

45. These tests disclose the fact that any limitation of the active portion of the grate reduces the maximum capacity of the locomotive and the practice of reducing the grate should not be permitted with either high or low volatile coal.

Conclusions (Grates With Solid Ends).

46. From these tests it appears that there is no advantage shown by the solid grate. The evaporation per pound of coal is not improved, and there is more smoke than with the standard grate. (Paragraphs 41 and 42.)

Recommendations (Grates With Solid Ends).

47. There is little promise of important developments in smoke prevention from such devices as this solid end grate, and our recommendations are, that further efforts in the improvement of combustion be directed along other lines.

C. D. YOUNG,
Engineer of Tests.

Approved:
J. T. WALLIS,
General Supt. Motive Power.

Test Department.
Altoona, Penna.,
August 31, 1912.

M. P. 394A
8 – 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No. 8

TEST NOS., 1200.399 to 1200.410

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

SUBJECT: Standard and Solid End Grates

ALTOONA, PA., 4-20-1912

No.	Item	Value
	DRIVING WHEELS	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	ENGINE TRUCK WHEELS	
14	Number	2
15	Diameter, inches	30
	TRAILING WHEELS	
16	Diameter, inches	–
	WHEEL BASE, FEET	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	21667
21	" 1st Drivers	45667
22	" 2d "	42583
23	" 3d "	47500
24	" 4th "	40850
25	" 5th "	–
26	" Trailers	–
27	Total	198267
28	" on Drivers	176600
	CYLINDERS	
	Diam. and Stroke, H. P	22 x 28
	" " " L. P	–
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.5
41	" " Crank "	10.7
42	" Left, Head "	12.2
43	" " Crank "	10.8
44	L. P. Right, Head "	–
45	" " Crank "	–
46	" Left, Head "	–
47	" " Crank "	–
	RECEIVER, CUBIC FEET	
48	Volume Right Side	–
49	" Left "	–
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	30
51	" " Width	2
58	L. P. " Length	–
59	" " Width	–
66	H. P. Exhaust, Length	No port
67	" " Width	–
70	L. P. " Length	–
71	" " Width	–

No.	Item	Value
	PISTON RODS, DIAMETER INCHES	
74	High Pressure	4
76	Low "	–
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	
80	Low "	–
	VALVES	
82	Type	Piston
83	Design	Amr. Bal. Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walschaerts
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	6.25
88	Low " "	–
	Steam LAP OF VALVE	
90	High Pressure, inches	.91
94	Low " "	–
	Exhaust LAP OF VALVE	
98	High Pressure, inches	Neg. .06
102	Low " "	–
	BOILER	
113	Type	Belpaire, Wide Firebox
114	Outside Diam. 1st Ring	71.16
	TUBES	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.6875
118	Length Between Tube Sheets, inches	164.28
119	Total Fire Area, sq. ft.	6.23
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	–
126	Outside Diam. " inches	–
128	Length of " "	–
	FIREBOX, INSIDE, INCHES	
132	Length	118.32
133	Width	65.04
137	Air Inlets to Ashpan, sq. ft.	7.56
	GRATES	
144	Type	Rocking finger
145	Grate Area, sq. ft.	48.66
146	Area of Dead Grates	0
	Air inlets through grates sq. ft.	15.41

No.	Item	Value
	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2673.68
155	" " " Fire "	2339.23
156	" " Firebox, " "	166.06
157	" " Superh'r, " "	–
*158	Total, Based on " "	2505.29
159	" " " " " of Firebox and Water Side of Tubes	2839.74
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	349.7
161	Steam " " "	83.1
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.63
167	Area, sq. inches	24.89
	REVERSE LEVER	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	–
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	51.49
172	Fire Area Thru Tubes (119) to Grate Area (145)	.13
173	Firebox Heating Surface (156) to Grate Area (145)	3.41
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.09

*USED IN CALCULATIONS

DIMENSIONS OF THE H6b CLASS LOCOMOTIVE
on which the solid end grate tests were made.
Table 8.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Bulletin No. 8
FUEL: Jamison Coal

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Standard and Solid End Grate

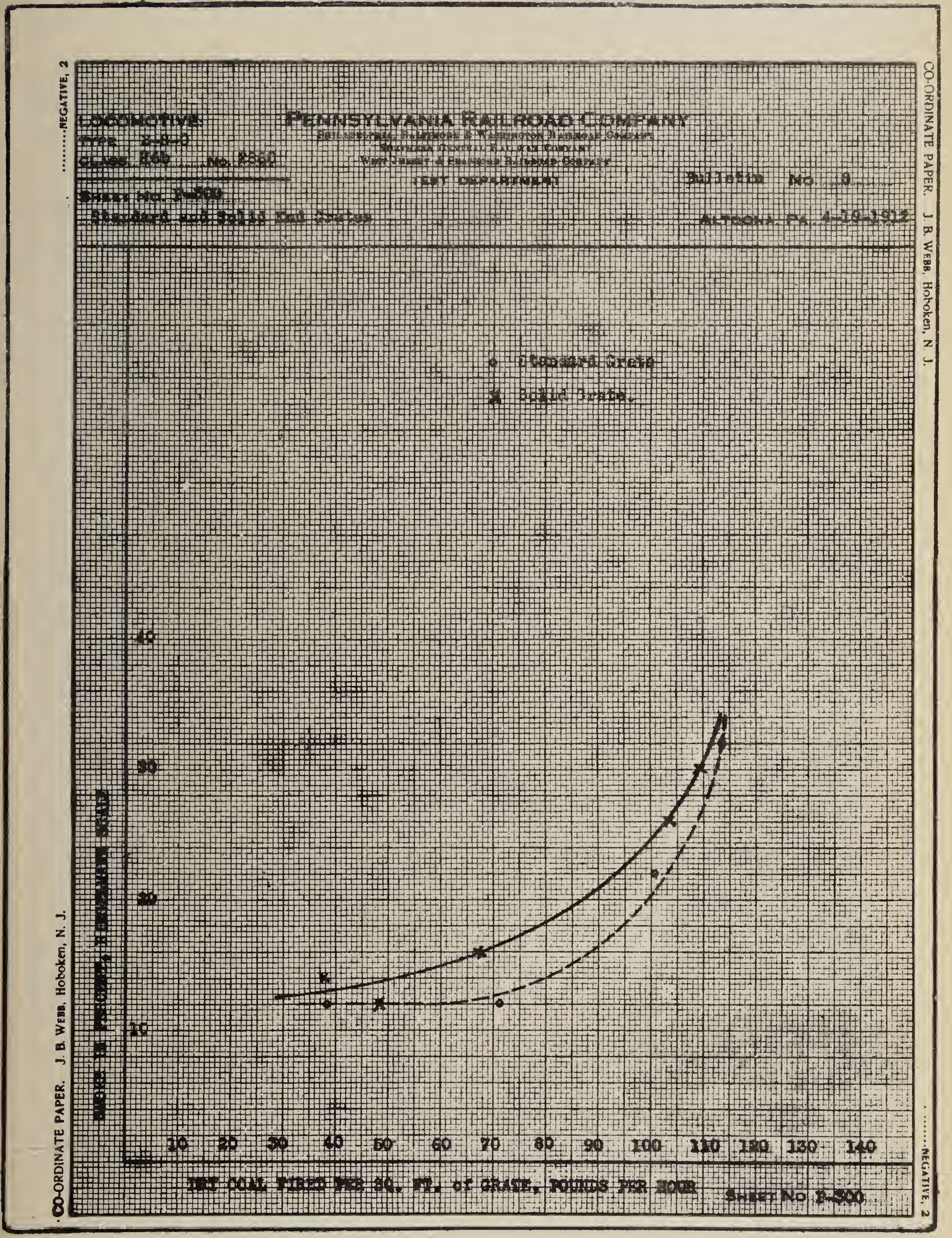
ALTOONA, PA., 4-20-1912

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Kind of Grate	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.400	80-20-F	2	12.86	Full		Standard	202.4	1.5	0	13540	19
1200.399	80-30-F	2	12.86	"		"	204.8	2.1	0	13393	24
1200.401	80-40-F	2	12.86	"		"	203.8	3.6	0	13540	69
1200.404	120-40-F	2	19.30	"		"	198.3	5.3	0.1	"	94
1200.410	120-45-F	1	19.30	"		"	202.9	5.6	0.2	"	254
1200.405	80-20-F	2	12.86	"		Solid End	204.8	1.4	-	"	17
1200.406	80-30-F	2	12.86	"		"	203.0	2.1	0.1	"	27
1200.407	80-40-F	2	12.86	"		"	205.1	3.4	0.1	"	37
1200.408	120.40-F	2	19.30	"		"	187.8	5.0	0.1	"	94
1200.409	120-45-F	1	19.30	"		"	193.4	5.5	0.2	"	254

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour. Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour per Sq. Ft. of Fire Heating Sur.	Equivalent Evaporation from and at 212° F., Pounds: Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft in Firebox	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.400	1857	38.16	14850	18237	7.28	9.82	528.6	70.05	0.7		
1200.399	2346	48.21	17678	21509	8.59	9.17	623.4	66.13	0.8		
1200.401	3469	71.29	23844	29046	11.59	8.37	841.9	69.70	1.3		
1200.404	4893	100.56	30625	37273	14.88	7.62	1080.4	54.35	2.0		
1200.410	5530	113.65	33058	40153	16.03	7.26	1163.9	51.79	2.0		
1200.405	1833	37.68	14435	17457	6.97	9.52	506.0	67.91	0.6		
1200.406	2340	48.09	17416	21186	8.46	9.05	614.1	64.55	0.8		
1200.407	3274	67.28	23467	28643	11.43	8.75	830.2	62.41	1.2		
1200.408	5042	103.62	31010	37785	15.08	7.49	1095.2	53.43	1.9		
1200.409	5318	109.29	32510	39584	15.80	7.44	1147.4	53.06	2.2		

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	C O in Gases	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Smoke in Per cent
	214	379	380	381		265	383	384	385	398	399	
1200.400	14308				0	14034	481.4	3.86	29.72		4.87	12
1200.399	17400				0	18827	645.8	3.63	26.94		5.23	12
1200.401	23466				0.2	24968	856.5	4.05	27.40		4.64	12
1200.404	30254				0	20301	1044.6	4.68	28.96		4.02	22
1200.410	32658				0.8	21743	1118.7	4.94	29.19		3.80	32
1200.405	14220				0	14176	486.3	3.77	29.24		4.99	14
1200.406	17205				0	18497	634.5	3.69	27.12		5.09	12
1200.407	23170				0.4	25051	859.3	3.81	26.96		4.93	16
1200.408	30635				0	21002	1080.7	4.67	28.35		4.02	26
1200.409	32102				0.8	20564	1058.1	5.03	30.34		3.74	30

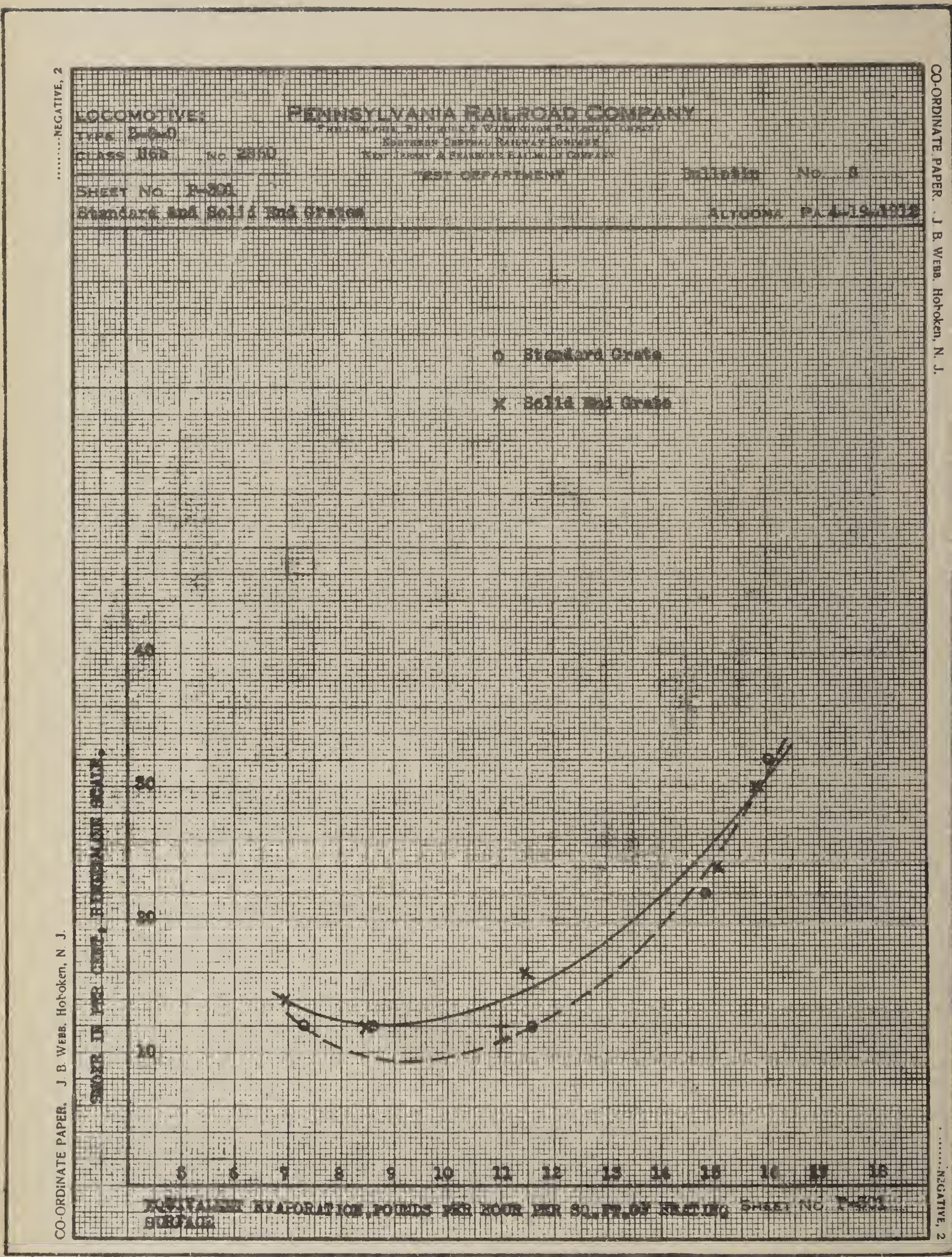
RESULTS OF TESTS OF SOLID END AND STANDARD GRATES.
Jamison Coal.
Table 9.



SMOKE, AND COAL FIRED.

The solid end grates make a little more smoke than the regular form of grate. Jamison Coal.

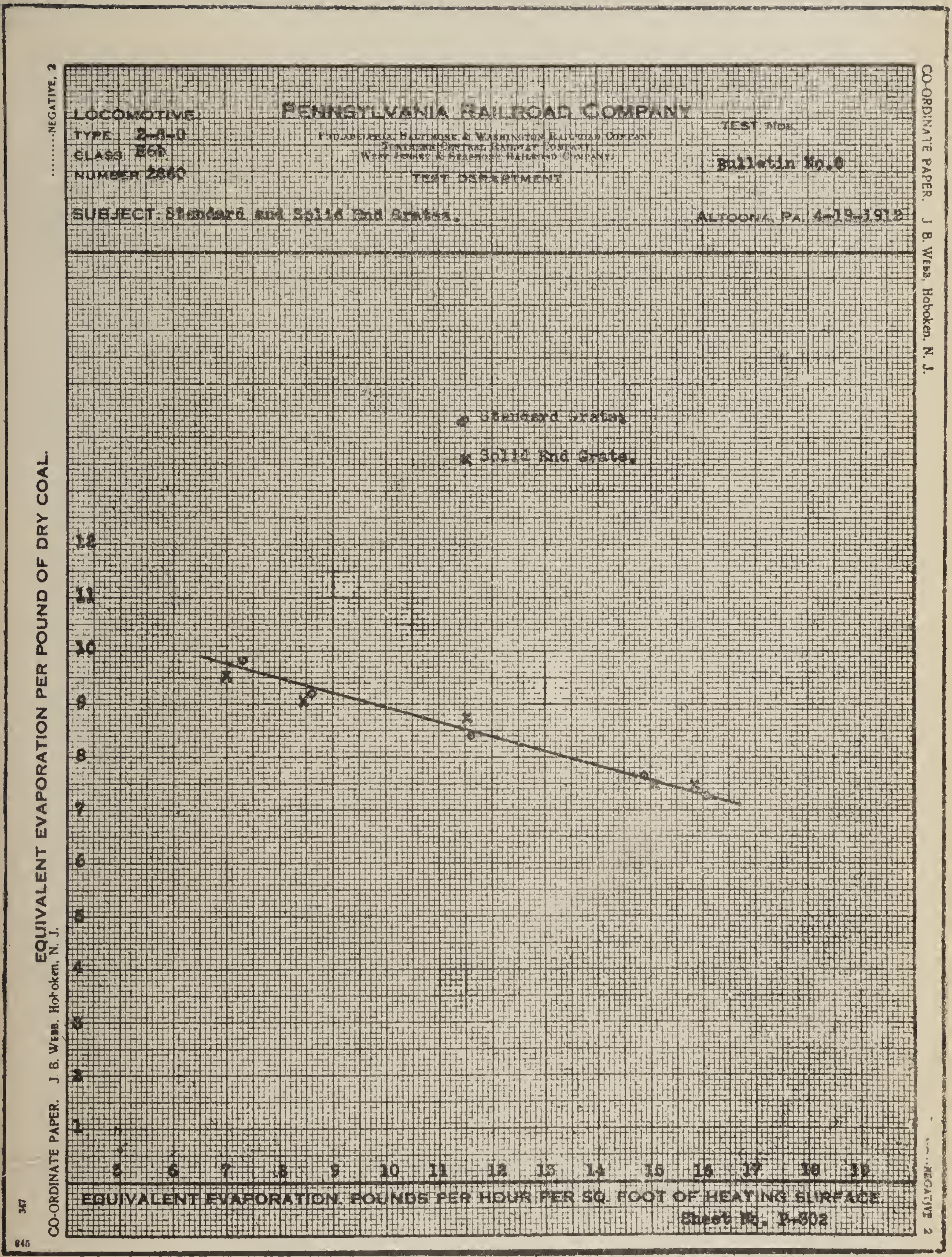
Fig. 13.



SMOKE AND EVAPORATION.

The solid end grate again shows more smoke than the standard grate. Jamison Coal.

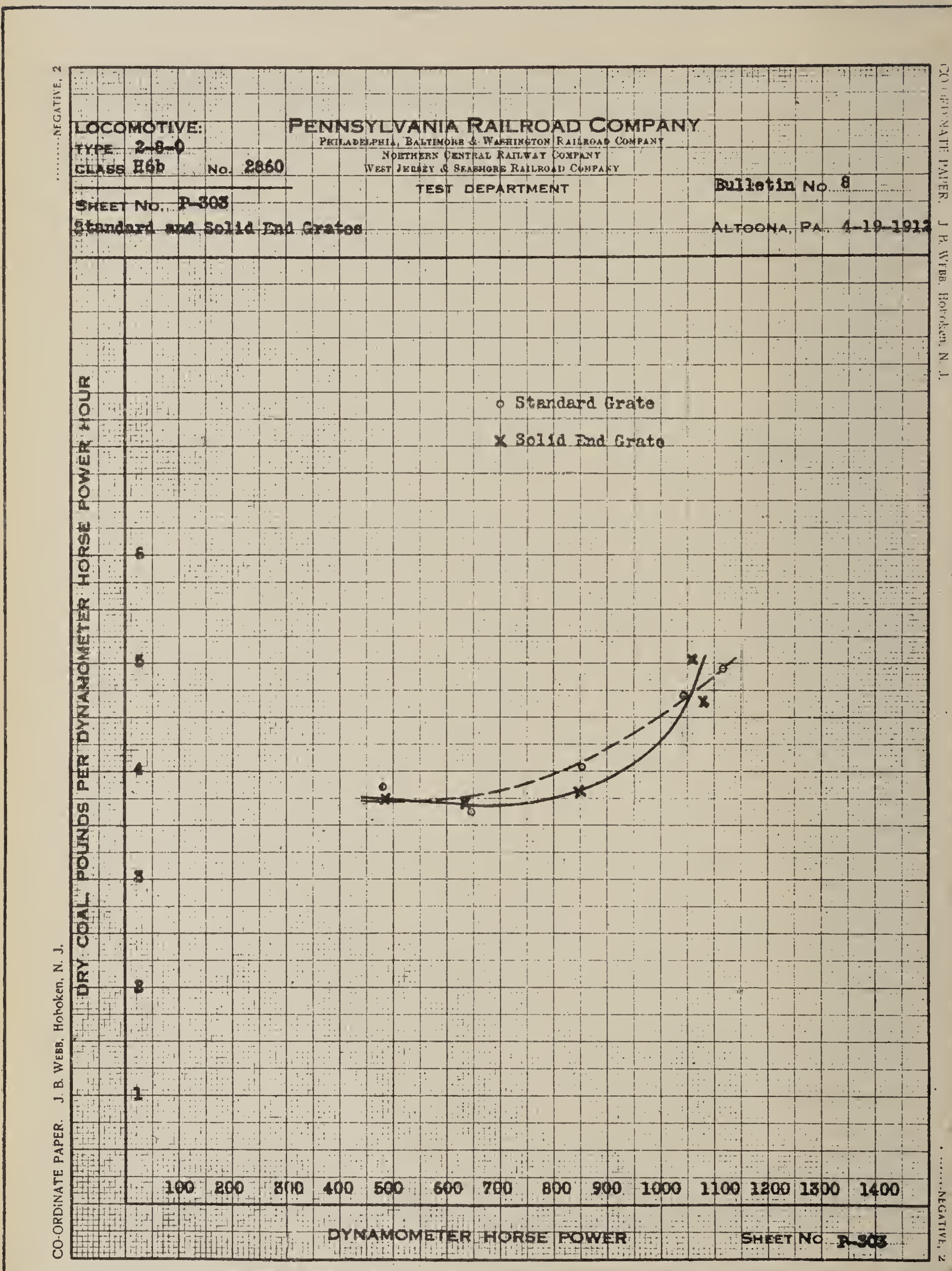
Fig. 14.



EVAPORATION PER POUND OF COAL AND RATE OF EVAPORATION.

No difference can be found between the two grates. Jamison Coal.

Fig. 15.



COAL PER DYNAMOMETER OR DRAWBAR HORSEPOWER, AND DYNAMOMETER HORSEPOWER.

There is little or no difference between the two grates. Jamison Coal.

Fig. 16.

GRAPHICAL LOG OF TEST.

The following diagrams show the boiler pressure, speed, drawbar pull and weight of coal and water for each ten minute interval of the test. A diagram is drawn for each test and is on file with the Test Plant records. A few representative diagrams are shown here.

M. P. Experimental D-1 | 12 9 1011 8 x 10½

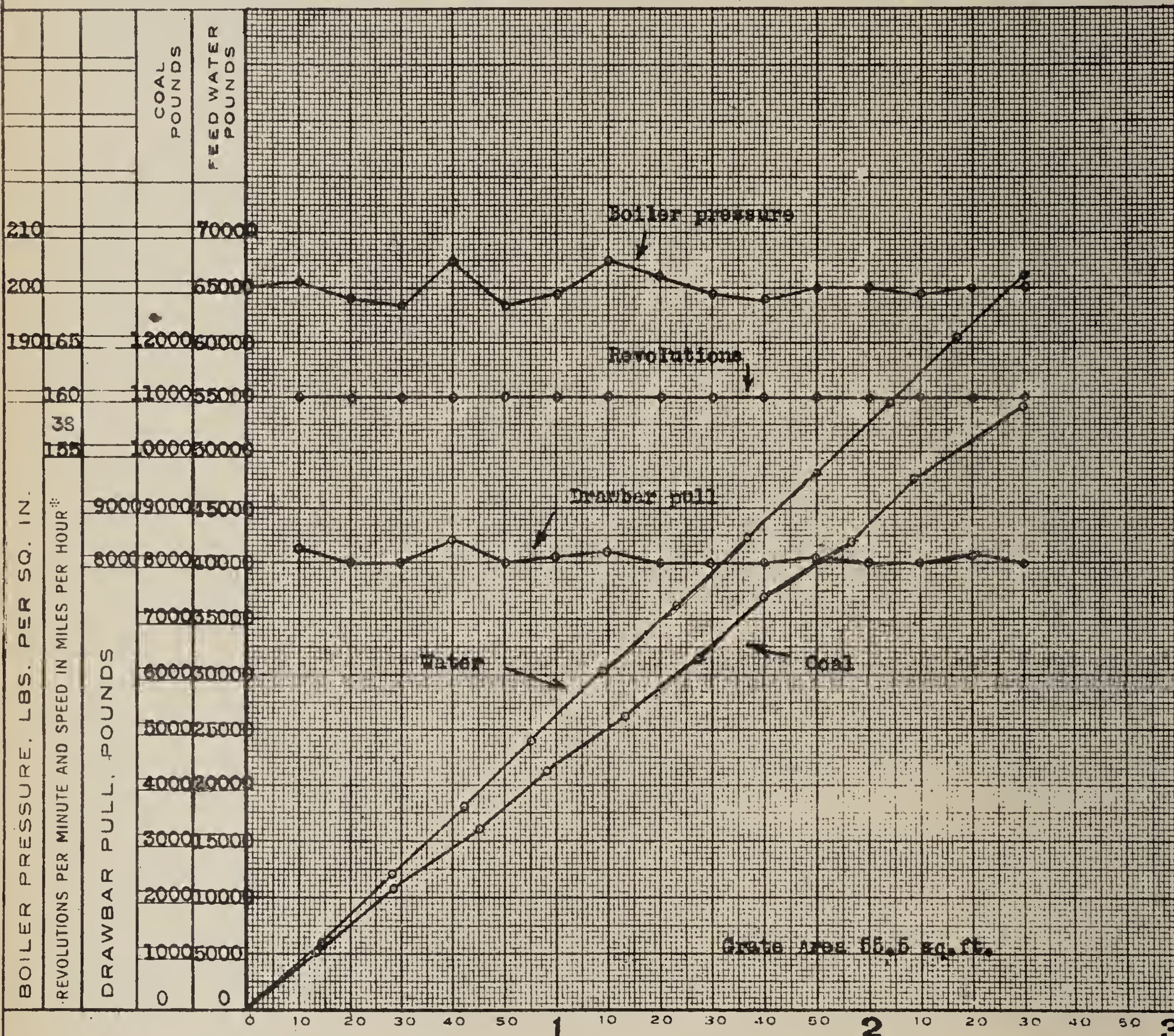
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-314 | TEST DEPARTMENT | Bulletin No. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced | ALTOONA, PA., 12-19-06



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	25	Full	6.11

TEST NO. 916

SHEET NO. P-314

M. P. Experimental D-1

12 9 1911
8 x 10½

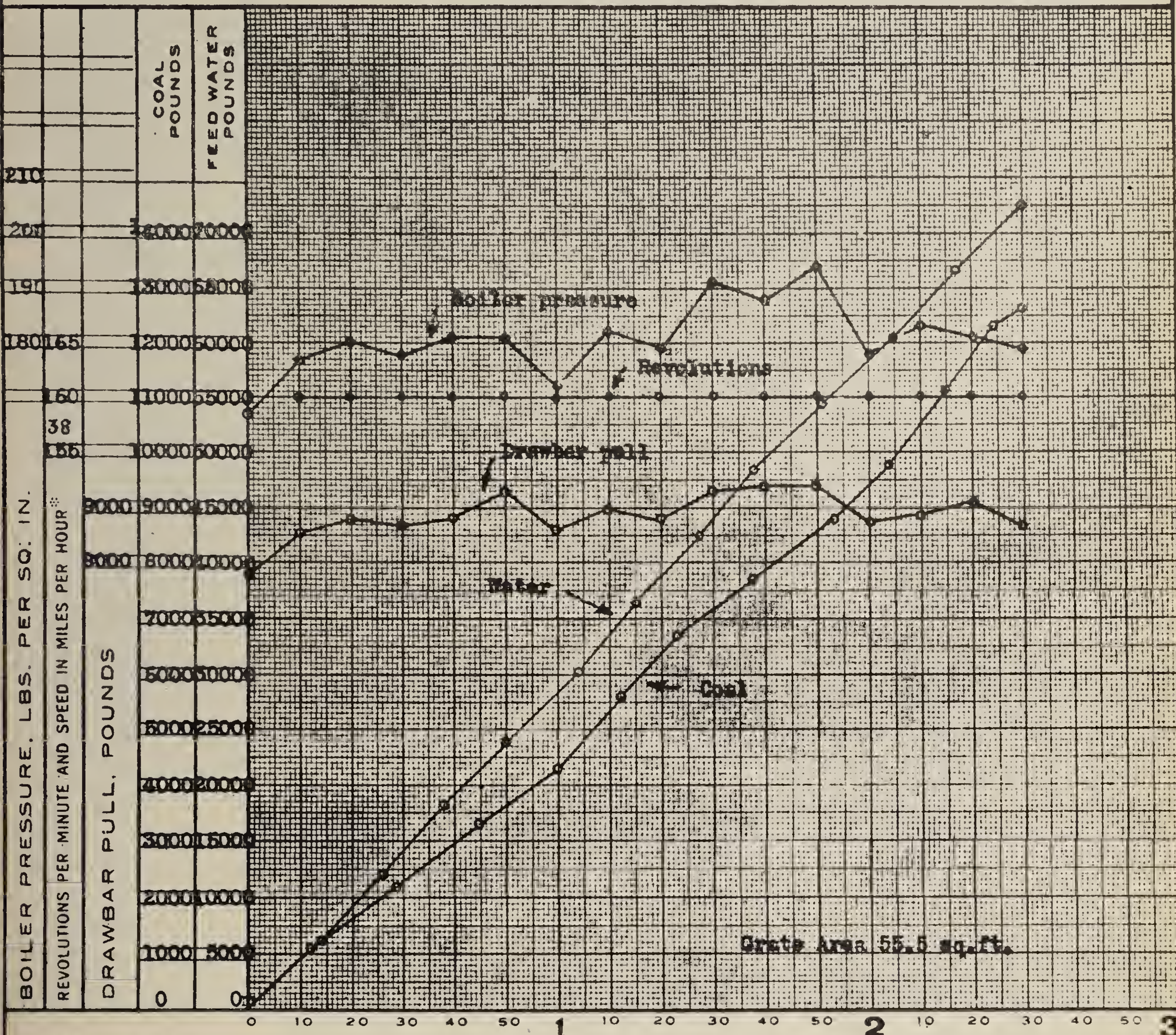
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-315 TEST DEPARTMENT Bulletin NO. 6

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 11-28-06



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	27	Full	5.73

TEST NO. 917

SHEET NO. P-315

M. P. Experimental D-1

12.9 19½
8 x 10¾

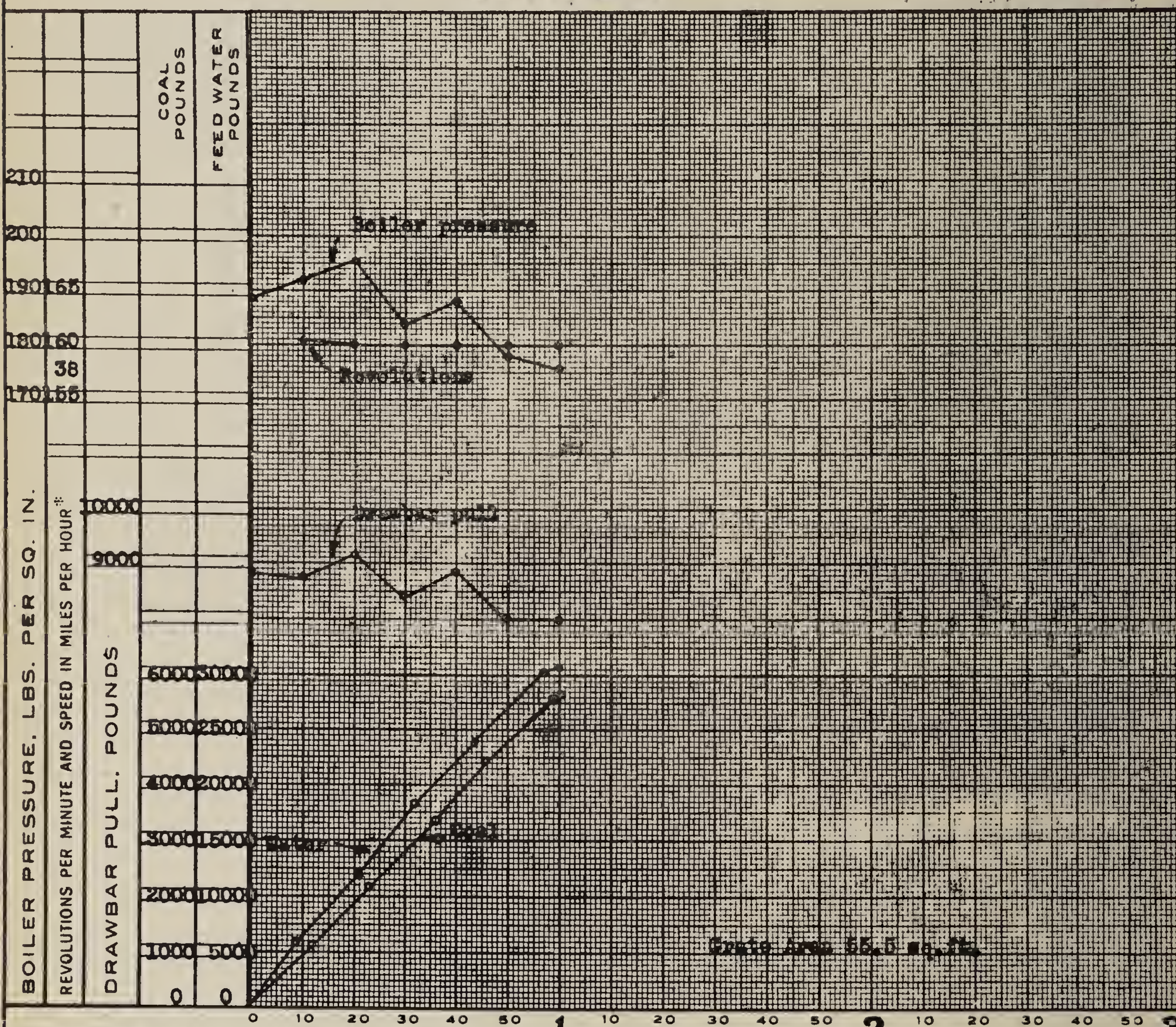
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-316 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 11-26-06



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	30	Full	5.43

TEST NO. 918

SHEET NO. P-316

M. P. Experimental D-1

12 D 1911
8 x 10¼

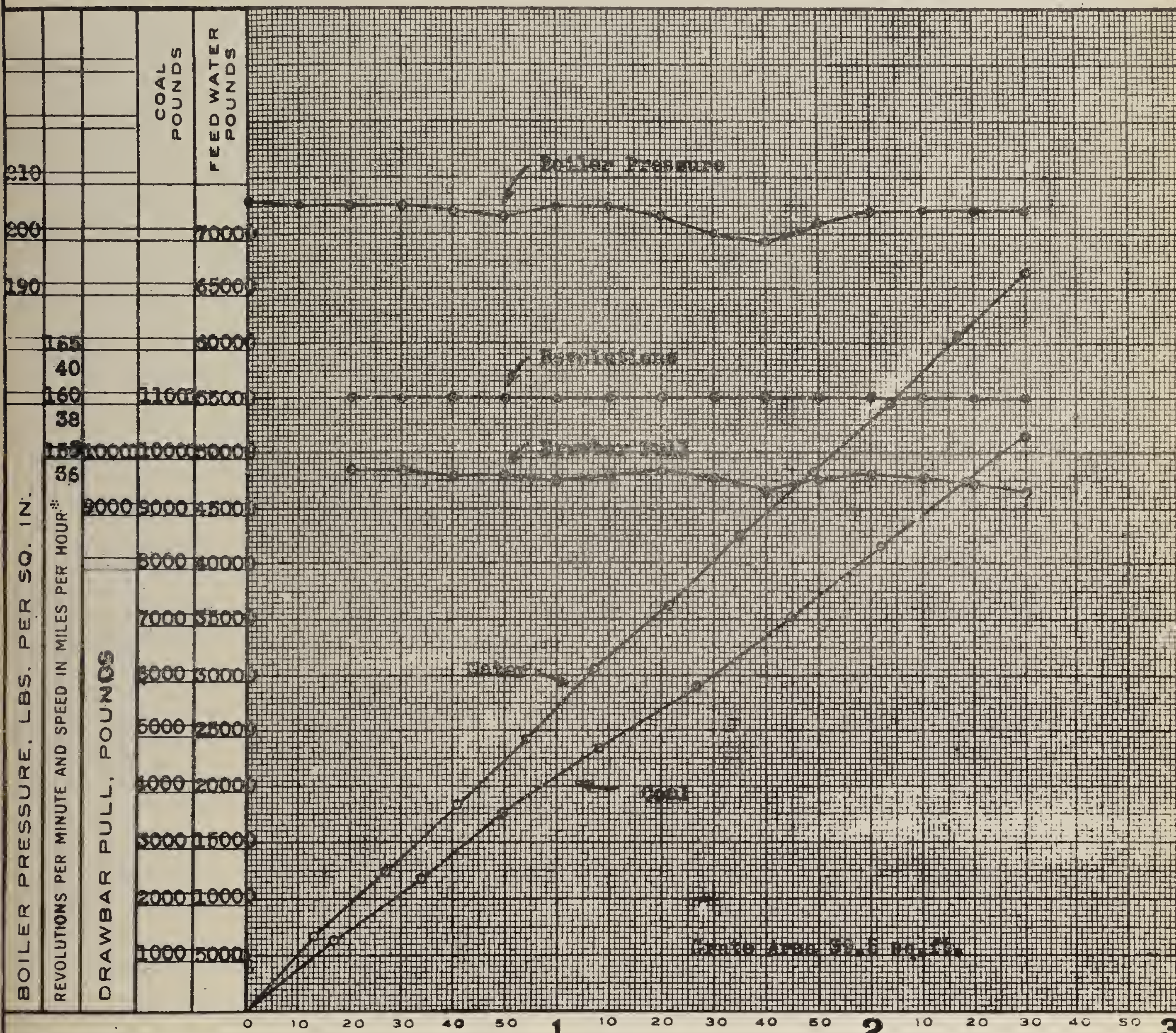
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-317 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced. ALTOONA, PA., 4-10-1907



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.78	160	25	Full	6.62

TEST NO. 926

SHEET NO. P-317

M. P. Experimental D-1

13 9 1911
8 x 10½

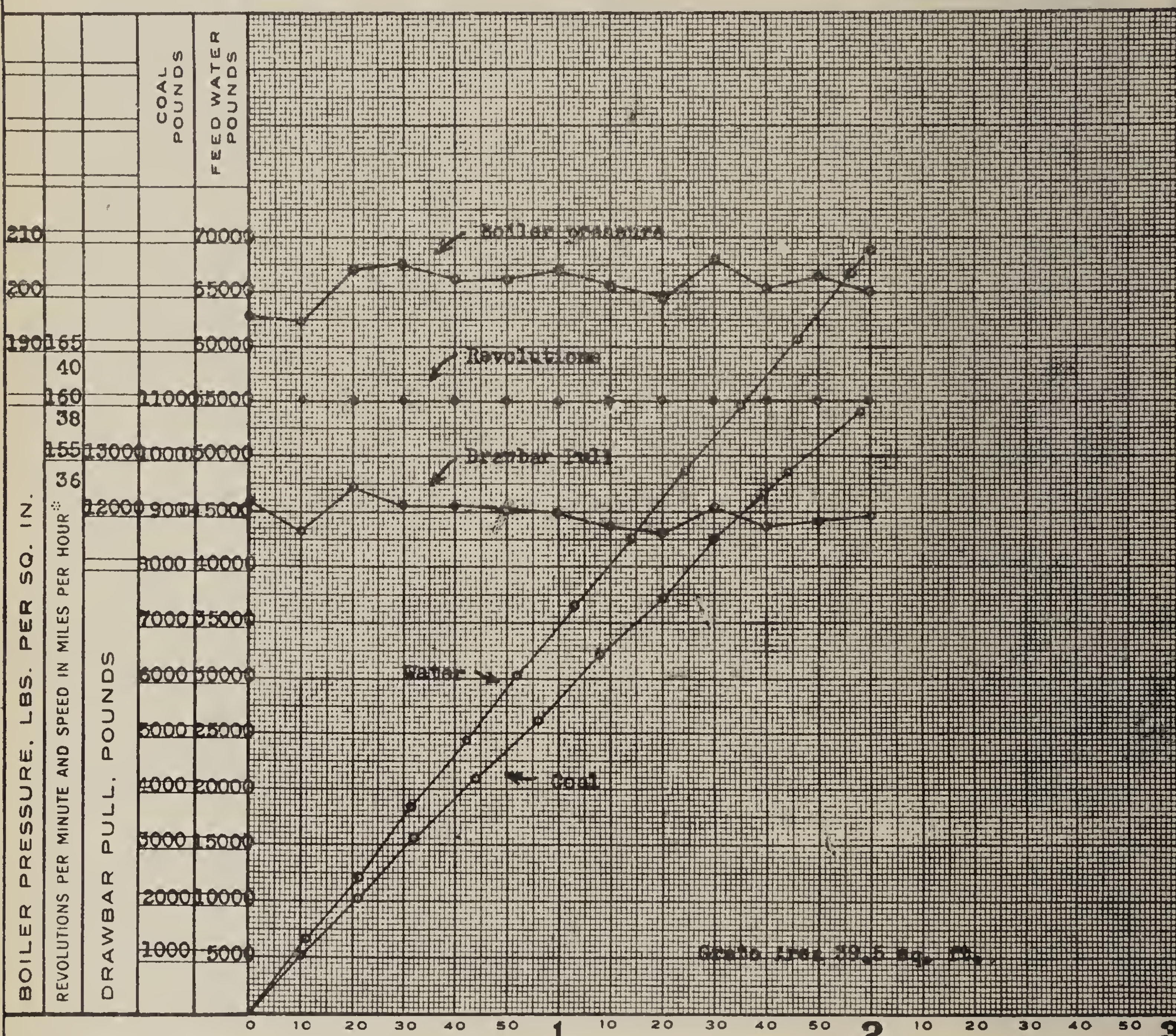
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-318 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced. ALTOONA, PA., 4-11-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.78	160	32	Full	6.29

TEST NO. 928

SHEET NO. P-318

M. P. Experimental D-1

12 9 1911
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

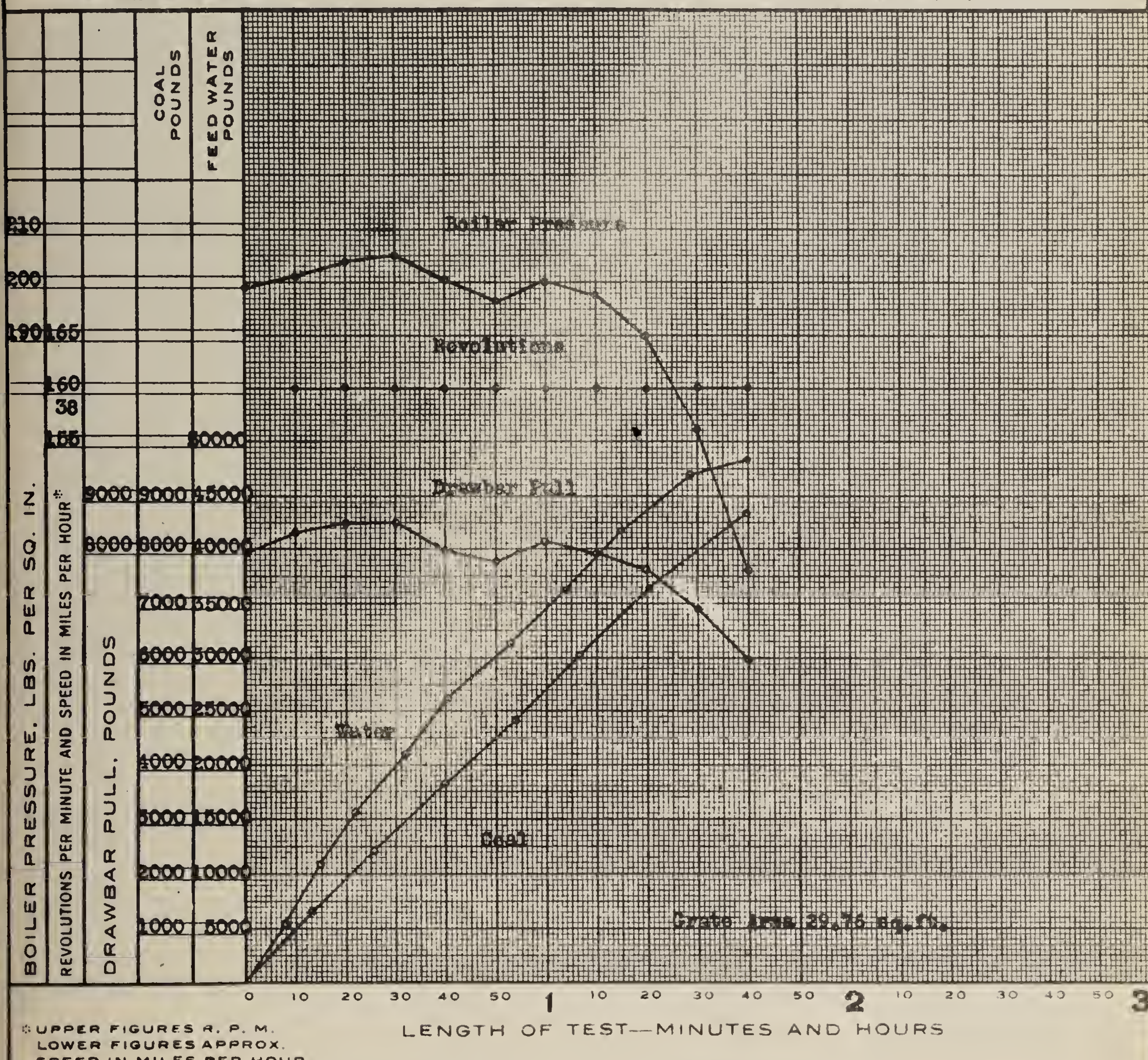
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-319 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced

ALTOONA, PA., 1-29-1907



LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	25	Full	5.57

TEST NO. 944

SHEET NO. P-319

M. P. Experimental D-1

12 9 1911
8 x 10½

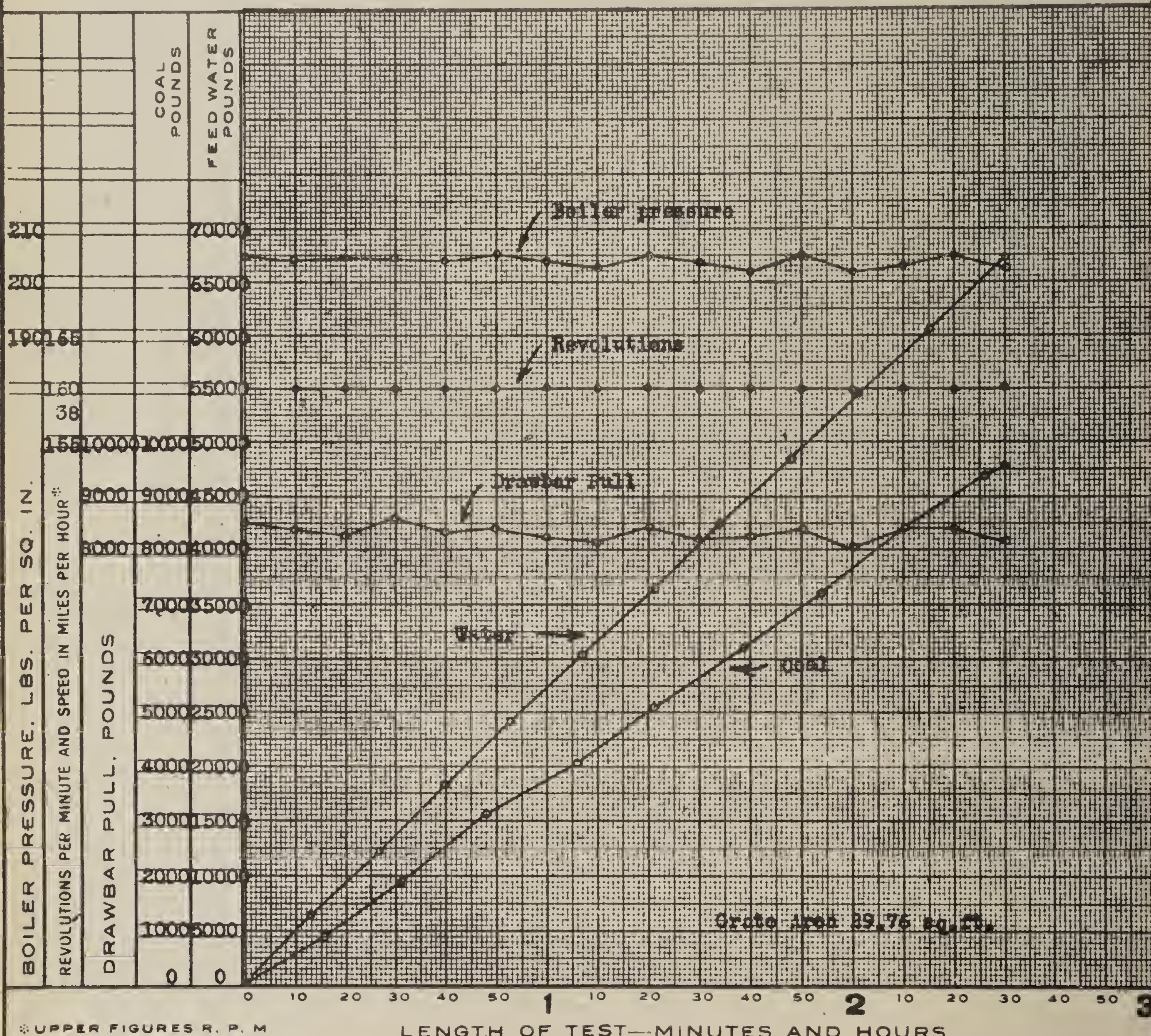
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-320 TEST DEPARTMENT Bulletin No. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 1-31-07



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	25	Full	7.04

TEST NO. 945

SHEET NO. P-320

M. P. Experimental D-1

12 9 1911
8 x 10½

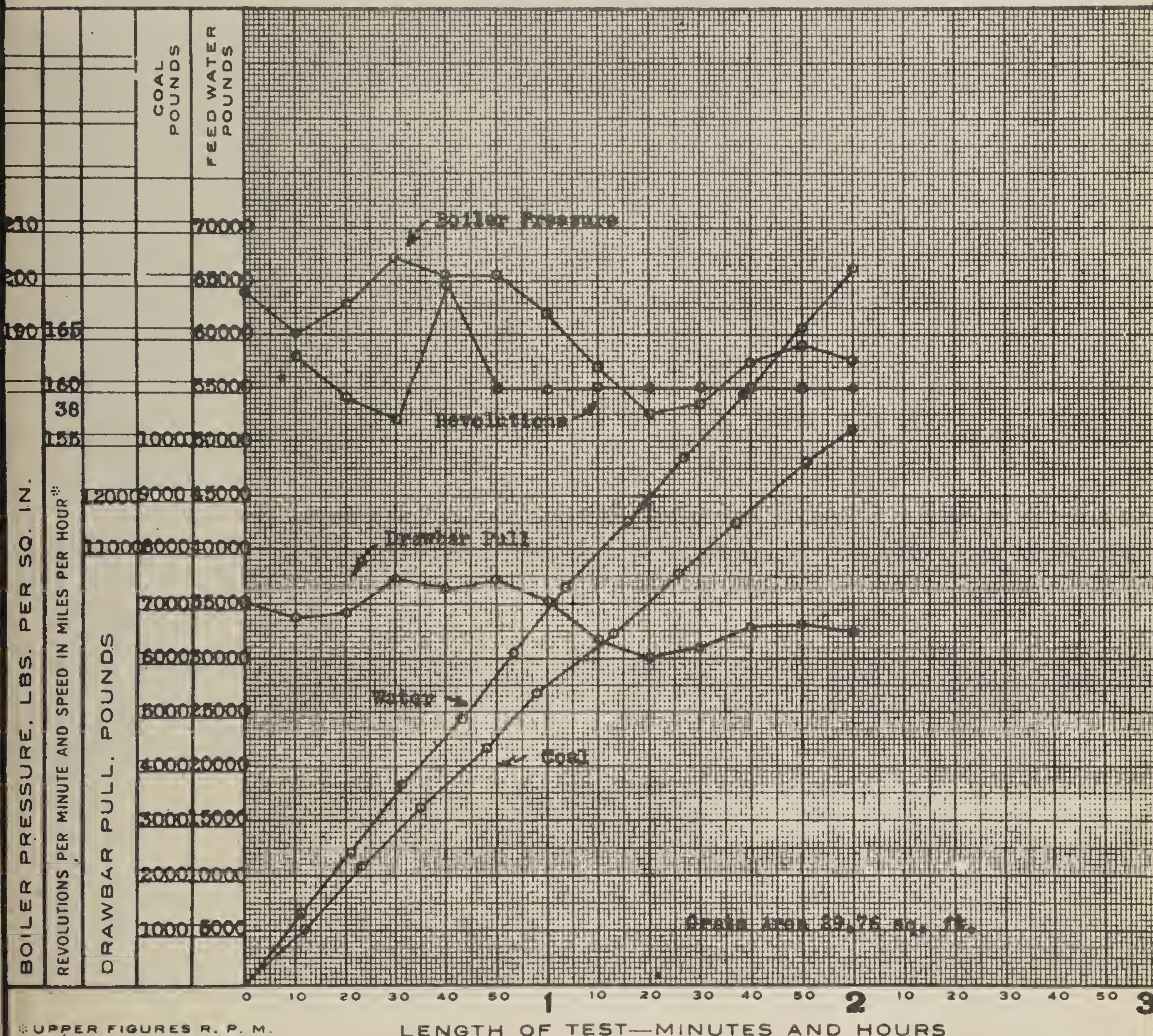
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-321 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced. ALTOONA, PA., 2-5-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.20	160	32	Full	6.62

TEST NO. 947

SHEET NO. P-321

M. P. Experimental D-1

12 9 1911
8 x 10½

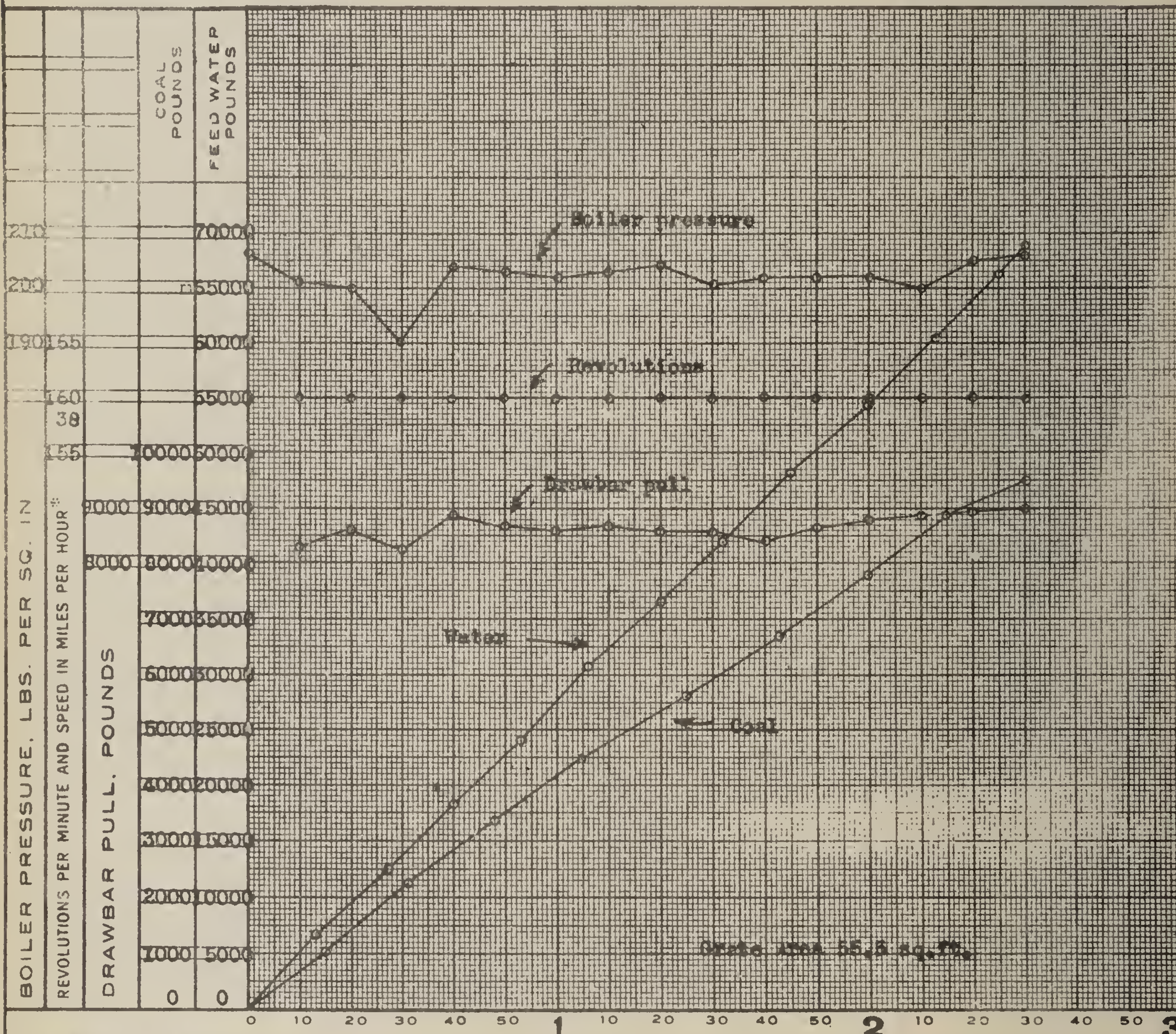
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-322 TEST DEPARTMENT Bulletin No. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 3-8-07



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.0	160	25	Full	7.23

TEST NO. 952

SHEET NO. P-322

M. P. Experimental D-1

12 9 1911
8 x 10½

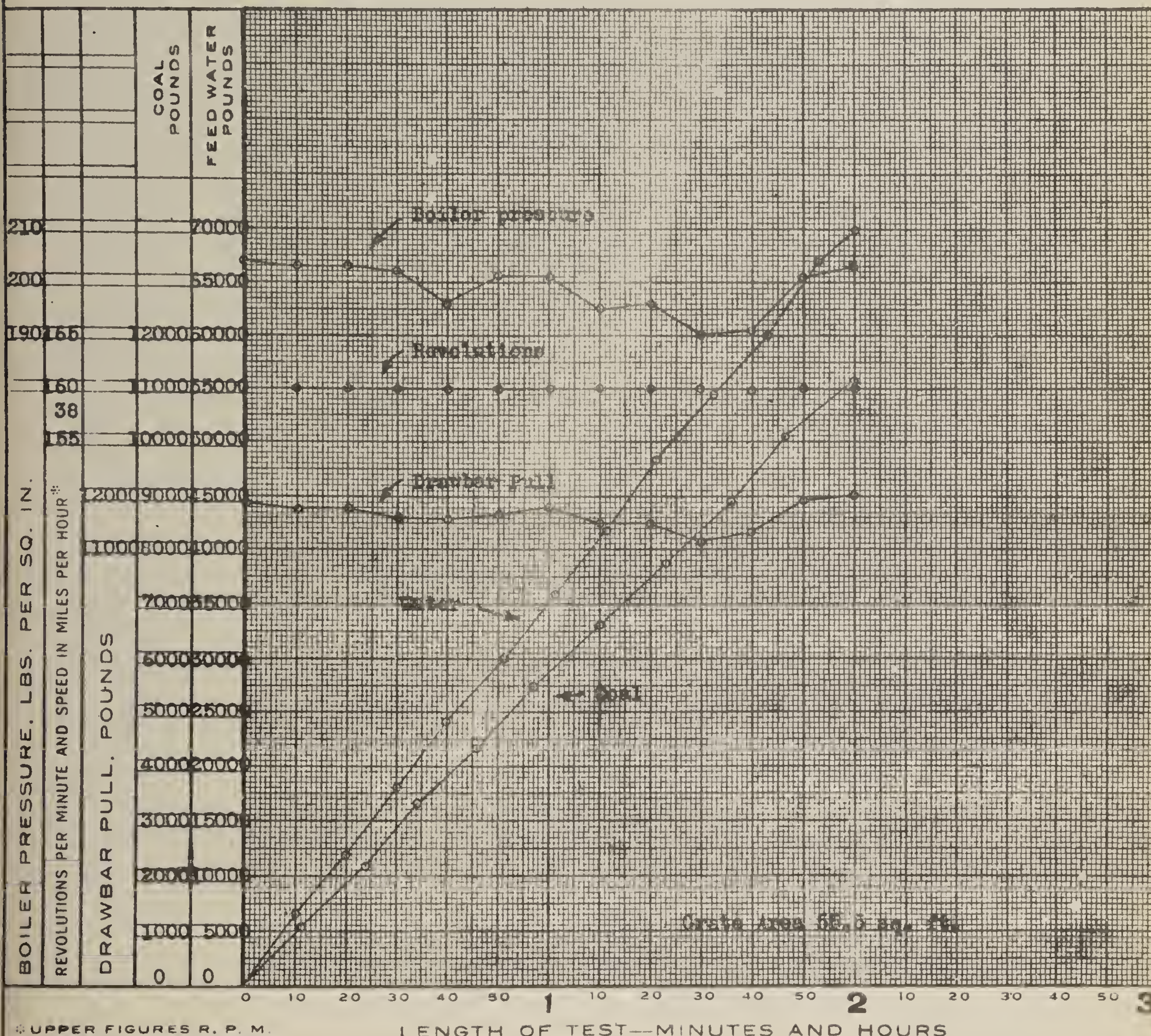
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-323 TEST DEPARTMENT Bulletin No. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grate Area Reduced ALTOONA, PA., 3-9-07



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.0	160	32	Full	6.33

TEST NO. 953

SHEET NO. P-323

M. P. Experimental D-1

12 • 1911
8 x 10½

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PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
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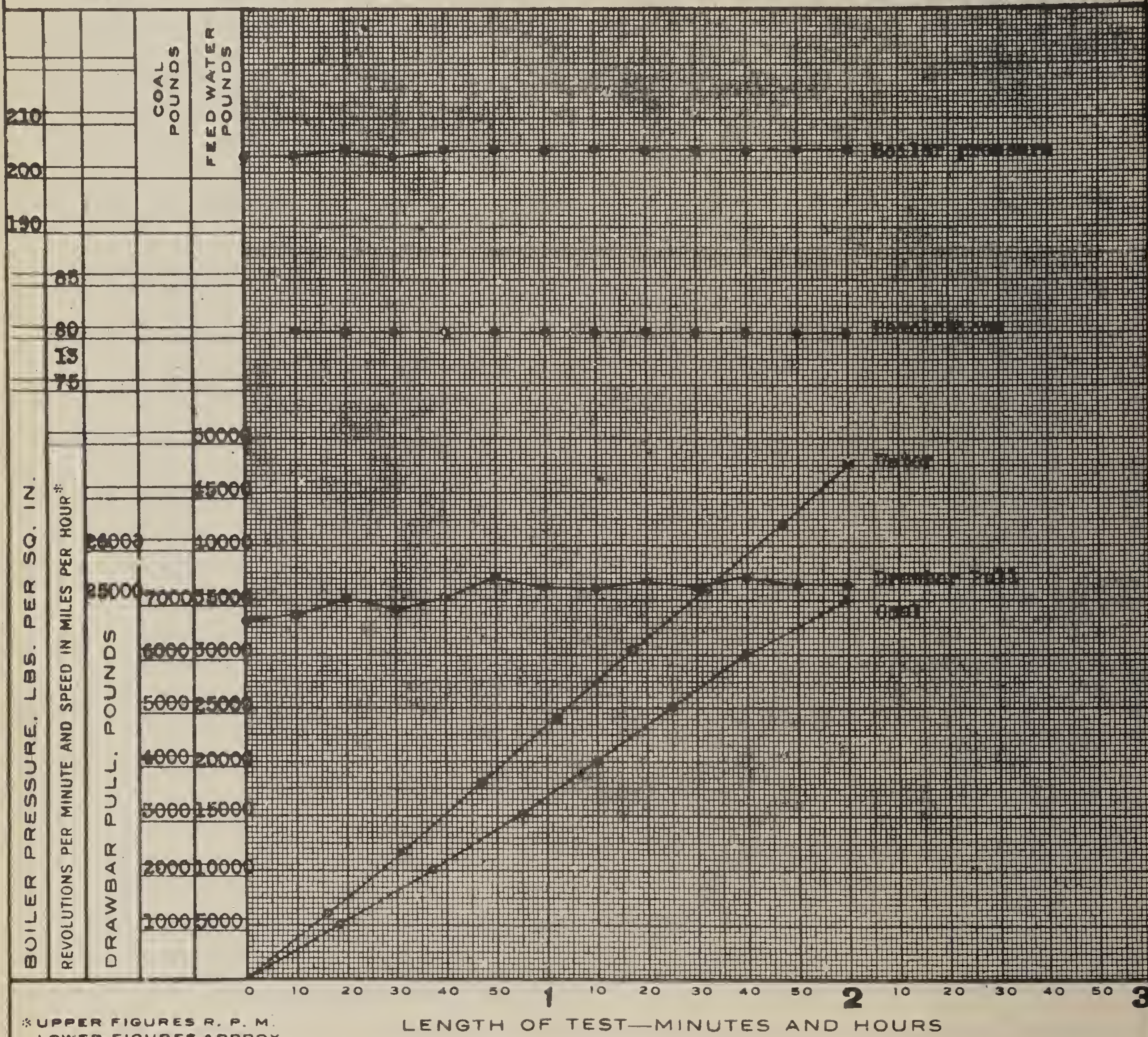
SHEET NO. P-324 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grates With Solid Ends ALTOONA, PA. 12-17-1909.



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
12.86	80	40	Full	6.81

TEST NO. 1200.401

SHEET NO. P-324

M. P. Experimental D-1

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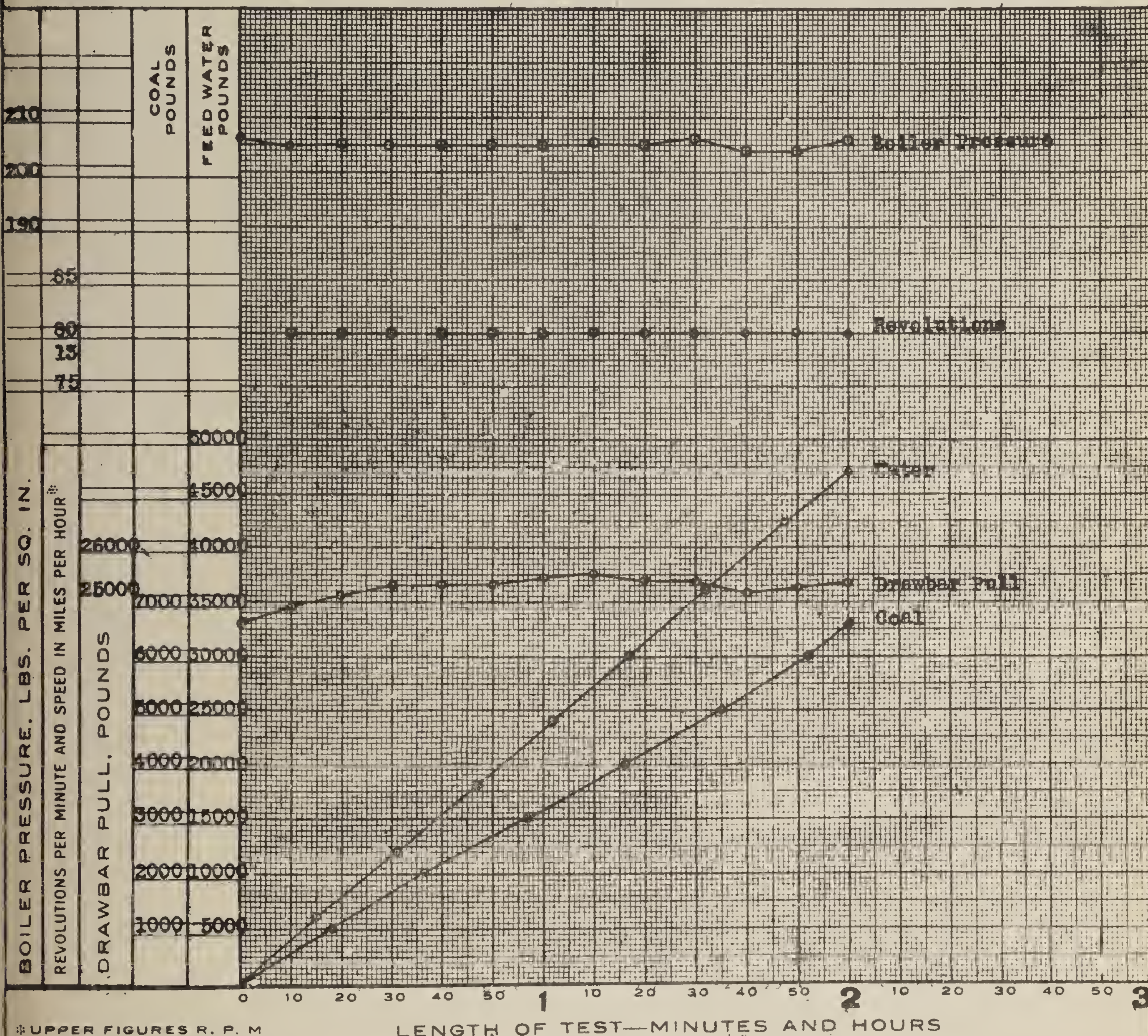
SHEET NO. P-325 TEST DEPARTMENT Bulletin NO. 8

GRAPHICAL LOG OF LOCOMOTIVE TEST

Grates with Solid Ends ALTOONA, PA. 12-22-1909



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water pe Pound of Coal
12.86	80	40	Full	7.10

TEST No. 1200.407

SHEET NO. P-325

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant
AT
ALTOONA, PENNA.

BULLETIN No. 9 (Revised)

Formerly Bulletins Nos. 11 and 28

SELF-CLEANING FRONT END

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1912

THE E3a CLASS ATLANTIC TYPE LOCOMOTIVE.
The type of locomotive used in the Front End tests.

CONTENTS.

I. Self-Cleaning Front End for E Class Locomotive.

II. Self-Cleaning Front End with H6b Class Locomotive.

LOCOMOTIVE TESTING PLANT.

SELF-CLEANING FRONT END FOR E CLASS LOCOMOTIVE.

The development of a Self-Cleaning Front End for the E Class or Atlantic Type Locomotive.

Conclusions and Recommendations on page 52.

INTRODUCTION.

1. In this bulletin is described the development of a self-cleaning front end for our Atlantic Type locomotive, and a comparison is made of some forms of front ends on our Consolidation locomotives. The results of the experiments lead us to believe that satisfactory self-cleaning front end arrangements have been found which will increase the capacity of these locomotives for sustained runs without decreasing their efficiency.

2. Our locomotive smokeboxes retain a large part of the cinders entering them from the tubes, and provision is made for cleaning them at terminals or at coaling points on the division. This regular cleaning out of the accumulated cinders is an expensive and troublesome operation, but a greater objection to the retention of cinders in the smokebox, is the fact that they fill the passage through which the gases are drawn, and interfere with the draft. Eventually, in many cases, the passages are so closed up that the locomotive fails entirely.

3. It has seemed desirable to remove these conditions, which limit the steaming of the locomotive, and various devices have been tried, the object of which is to cause all of the cinders to be discharged from the stack. The method of producing this self-cleaning effect, is to create, in the smokebox, a restricted opening, through which the cinders are drawn

in a rapidly moving stream of gases. If the passages in the smokebox are large, the flow of gases is too slow to carry along the cinders.

4. At the same time that the narrow passage is provided, the other parts in the smokebox must be adjusted so that the whole internal arrangement of the smokebox will act as a unit in creating sufficient draft upon the fire and in discharging the cinders.

5. This bulletin describes a series of experiments with locomotives of the E class, or Atlantic Type, and H6b class or consolidation type in developing smokebox arrangements that would be self-cleaning, and at the same time give good results in steaming.

6. Satisfactory results were finally attained for the E class with an arrangement as shown in Fig. 19 and for the H6b class in Fig. 25. The development of the E class front end will be the first described.

Description of Standard Front End.

7. The front end or smokebox arrangement now in use on a large number of our Atlantic Type passenger locomotives of the E class, is shown in Fig. 2. The outside stack is 16 inches in diameter at the base and has a taper of one inch diameter per foot of height. The inside stack is not tapered. The diaphragm plate is perforated and has an adjustable plate on the lower edge, a netting covering the perforations.

8. This arrangement will be referred to in the report as the standard front end.

9. A large number of tests of various kinds have been made, on the Testing Plant, with class E2a locomotive 5266 equipped with this standard front end, and while it has been found to be a very good arrangement, when it is frequently cleaned, so far as the steaming of the locomotive is concerned. It is not self-cleaning, and with friable coals, the accumulation of cinders in the front end may be as much as 1000 pounds per hour—a quantity that seriously interferes with the draft and necessitates cleaning of the front end at the end of an hour's run. With gas coals, the accumulation of cinders

is not so serious a matter, but even with these coals 300 pounds per hour or more may be collected and the smokebox must be cleaned at the end of each trip, where the locomotive

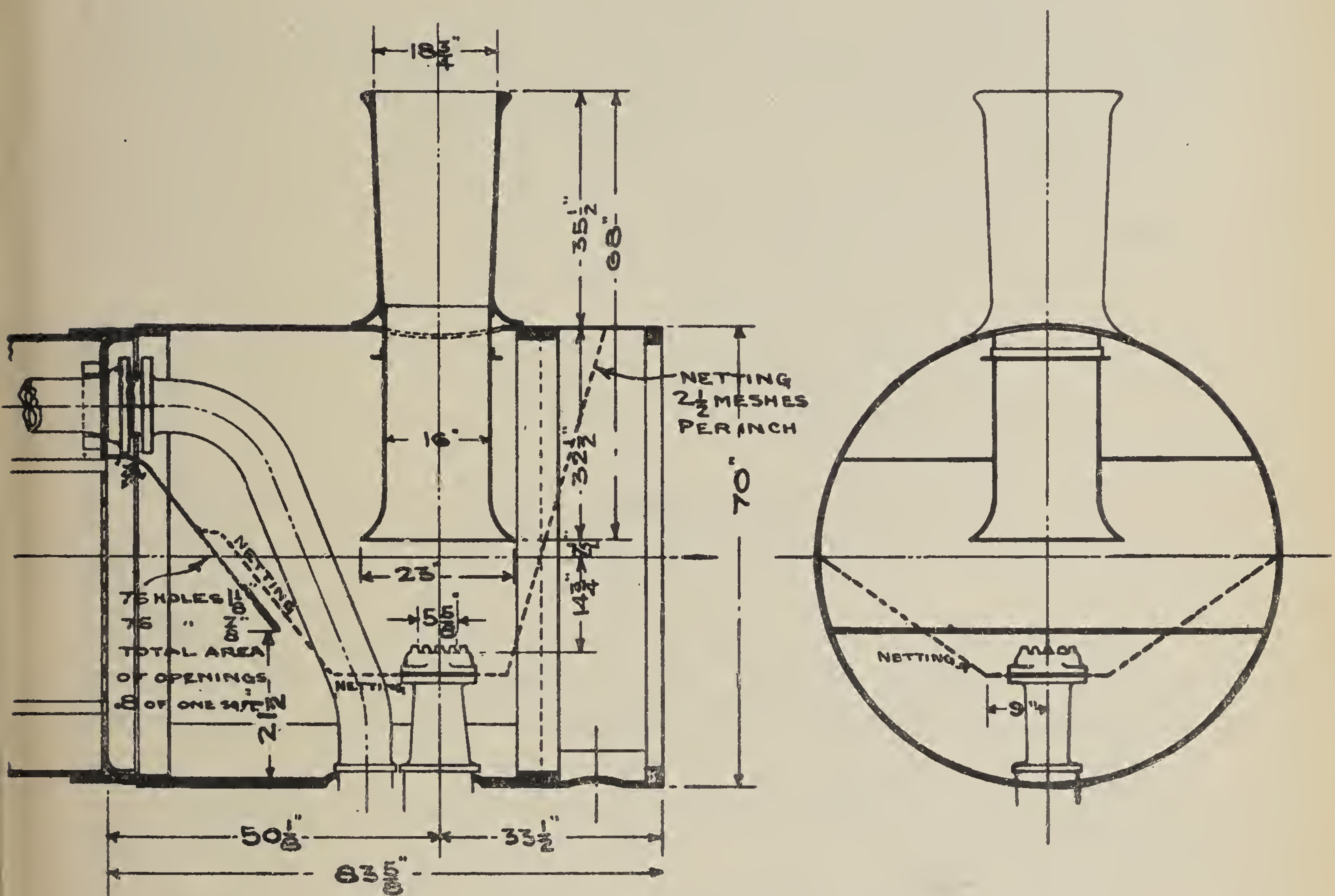

Fig. 2.

Standard front end arrangement E2a class locomotive. This form is not self-cleaning. A cinder trap is used with it. The diaphragm plate has 76 holes 1⅛ in. diameter and 75 holes ⅞ in. diameter. Its lower edge is adjustable. The part extending forward across the nozzle is made up of netting.

is working up to its capacity, and burned front ends result if there is any air leakage after cinders have collected.

Master Mechanics' Association Front End.

10. A committee, appointed by the American Railway Master Mechanics' Association, reported upon a series of front end tests that were made at Purdue University, with a

New York Central & Hudson River Railroad locomotive of the 4-4-2, or Atlantic Type (See Proceedings, American Railway Master Mechanics' Association, Volume XXXIX, 1906). Conclusions from these tests for a front end arrangement for best results, are given in the report as follows:

"A suggestion as to a standard front end is presented as Fig. 1, which, with the following equations referring thereto, may be accepted as a summary of conclusions to be drawn from all experiments made.

"For best results make H and h as great as practicable. Also make

$d = 0.21\ D + 0.16\ h.$
$b = 2d$ or $0.5\ D.$
$P = 0.32\ D.$
$p = 0.22\ D.$
$L =$ (Not well established) $= 0.6\ D$ or $0.9\ D$ but not of intermediate values."

11. These rules were used as the basis of a design of front end arrangement to be tried. No attempt was made, however, to have the lengths of the smokebox conform to those recommended, which could make it either 63 inches or 42 inches in length instead of the present 83⅝ inches for the E class locomotive.

12. In Fig. 1 the proportions of the front ends as finally developed, and which gave the best results on our locomotives, are shown in connection with the Master Mechanics' recommendations, for a best arrangement.

13. Our arrangements do not conform very closely to the Master Mechanics. One difference is in the length of inside stack (P). This length had to be increased in order to lift the cinders from the table plate or diaphragm. The longer inside stack, limits the diameter of bell (b), on account of the smaller space available near the top of the exhaust nozzle. The bell should not be circular, but should be extended on the sides to more completely cover the horizontal part of the plate. In these experiments, however, the bell was circular.

M. P. 479—A

8 x 10½
301 4-29-12

LOCOMOTIVE:
TYPE [redacted]
CLASS [redacted] No. [redacted]

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA BALTIMORE & WASHINGTON RAILROAD COMPANY
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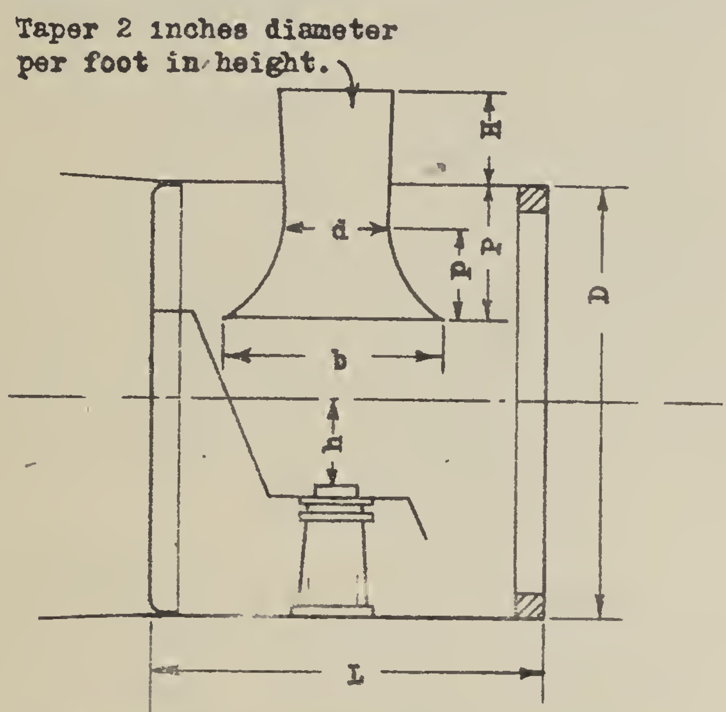
TEST DEPARTMENT

SHEET NO. P-353

Bulletin No. 9

Self Cleaning Front End

ALTOONA, PA. 8-30-1912



ARRANGEMENT OF FRONT END FOR BEST RESULTS

		Master Mechanics Association	E2a & E3a Classes	H6b Class
Stack throat	d	0.21 D + 0.16 h	0.21 D + 0.09 h	0.21 D + 0.87 h
" bell	b	2 d or 0.5 D	1.44 d or 0.33 D	1.32 d or 0.304 D
Length of inside stack	P	0.32 D	0.54 D	0.51 D
Length of bell	p	0.22 D	Not established	Not established
Length of Smokebox	L	Not well established 0.6 D or 0.9 D but not of intermediate values.	1.19 D	0.9 D

h - Tip of nozzle to center line of smokebox.
D - Diameter of smokebox.
H - Height of outside stack.

SHEET NO. P-353

Fig. 1.

Diagram of front end arrangement giving best results as shown in report of Master Mechanics' Association tests.

The Locomotive on Which the Tests Were Made.

14. An E2a class locomotive 5266, was used for most of the front end trials but later some of the devices were applied to E3a class locomotive 2984. An outline drawing of these classes is shown in Fig. 3 and the principal dimensions of the locomotives are given in Tables 3 and 7. The E3a locomotive differs from the E2a in diameter of cylinder only.

Draft and Back Pressure.

15. In the tests made by the Master Mechanics' Committee, oil was used for fuel and by its use the admission of air to the firebox could be completely controlled. With oil firing, the effectiveness of any arrangement could be derived from the draft indications; the draft in the smokebox at any fixed back pressure being dependent only upon the smokebox arrangement.

16. As our problem was to devise an arrangement that would clear the smokebox of cinders, the use of oil for fuel could not be considered, and with coal it was found impossible to duplicate draft readings under apparently similar conditions of running.

17. By means of a steam engine indicator connected to the exhaust pipe, a few inches below the nozzle, the back pressure was observed, and by running the locomotive under gradually increasing loads, a series of readings of the back pressure and corresponding draft or vacuum in the smokebox was obtained. These readings are plotted in Fig. 4, showing results for a light or thin fire on the grate. Fig. 5 shows a series of readings under similar conditions but with a heavy fire on the grate. A comparison of these diagrams indicates very clearly that the draft is so closely dependent upon the thickness of the fire that it cannot be used as a basis of comparison for different front end arrangements when firing coal.

18. In Fig. 6 the same readings of draft are shown in relation to the draft in front of the diaphragm. Here again the differences in draft conditions due to thickness of the fire are evident.

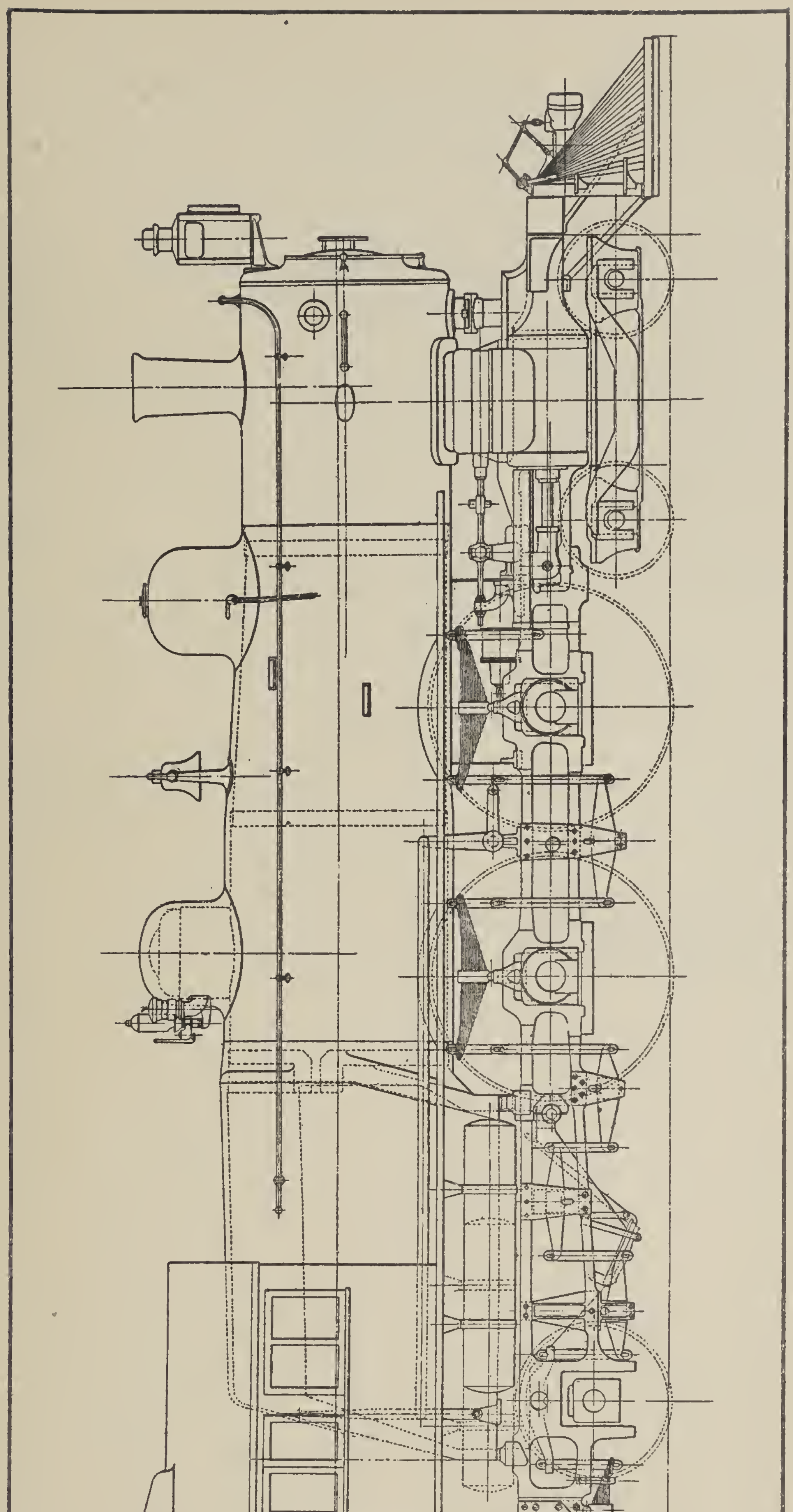


Fig. 3.
GENERAL ARRANGEMENT OF E2a AND E3a CLASS LOCOMOTIVE.

LEADING DIMENSIONS OF LOCOMOTIVE (E2a CLASS)

Total weight in working order, pounds	184,167
Weight on drivers, in working order, pounds	110,000
Cylinder (simple) size, inches	20½ x 26
Diameter of driving wheels, inches	80
Firebox heating surface, square feet	156.86
Heating surface of tubes (water side), square feet	2,471.04
Total heating surface (based on water side tubes), square feet	2,627.90
Total heating surface (based on fire side tubes), square feet	2,319.26
Grate area, square feet	55.5
Boiler pressure, pounds per square inch	205
Valves, type	Wilson double ported, slide
Valve gear	Stephenson
Firebox type	Wide, Belpaire
Number of tubes	315
Outside diameter of tubes, inches	2
Length of tubes, inches	180

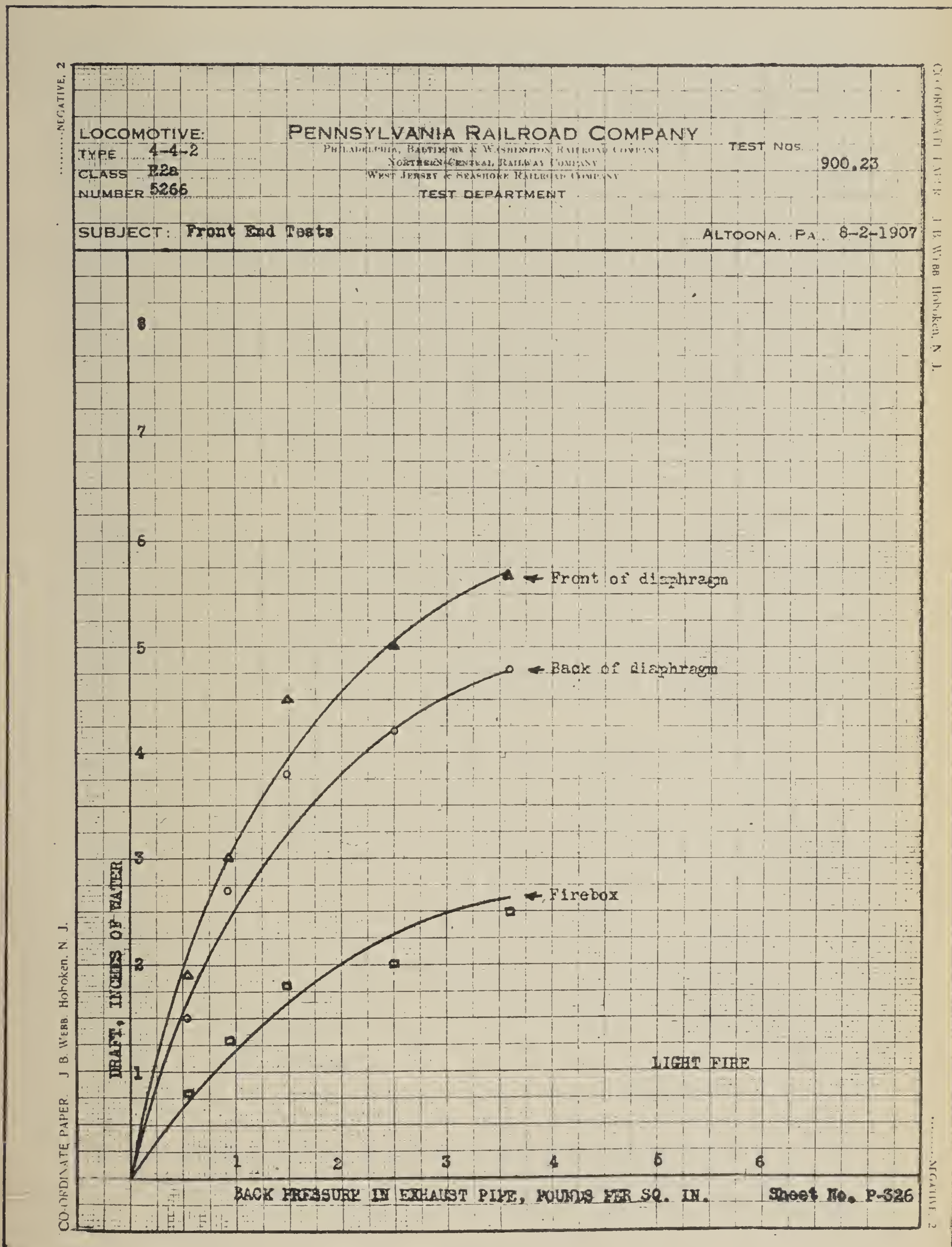


Fig. 4.
The draft in the smokebox and firebox with a thin or light fire.

19. With a light fire the loss in draft between the two sides of the diaphragm and between the front of diaphragm and the firebox decreases uniformly as the intensity of the draft increases.

20. With a thick fire the losses first increase to a maximum at about five inches of draft and then decrease with higher draft.

21. In estimating the comparative merits of the different devices tried, it then became necessary to take account of a number of factors, as:

The weight of cinders collected in the smokebox.

The quantity of water that could be evaporated as compared with the standard front end.

The evaporation per pound of coal, or the efficiency of the boiler.

The general steaming of the locomotive as shown by the boiler pressure during a test.

22. These methods, although logical, may appear to be indefinite and unscientific. There is at present no rational method for smokebox design and until much more careful investigations are made, comparisons of different smokebox arrangements cannot be based upon anything but very general considerations.

23. It would have added greatly to the value of the tests if the weight of sparks discharged could have been measured. At the time of the tests, however, apparatus for this purpose had not been perfected, and the cinders remaining in the smokebox were all that could be weighed.

24. From tests made with the standard front end it was known that the boiler could be expected to give an equivalent evaporation of about 16 pounds of water per square foot of heating surface, with Scalp Level coal, and 18 pounds with Penn Gas coal. To obtain the lower evaporation, a speed of 160 revolutions per minute and a cut-off of 27 per cent. was required with locomotive 5266 with fully open throttle, and for the higher evaporation of 18 pounds, 160 revolutions and 32 per cent. cut-off with full throttle.

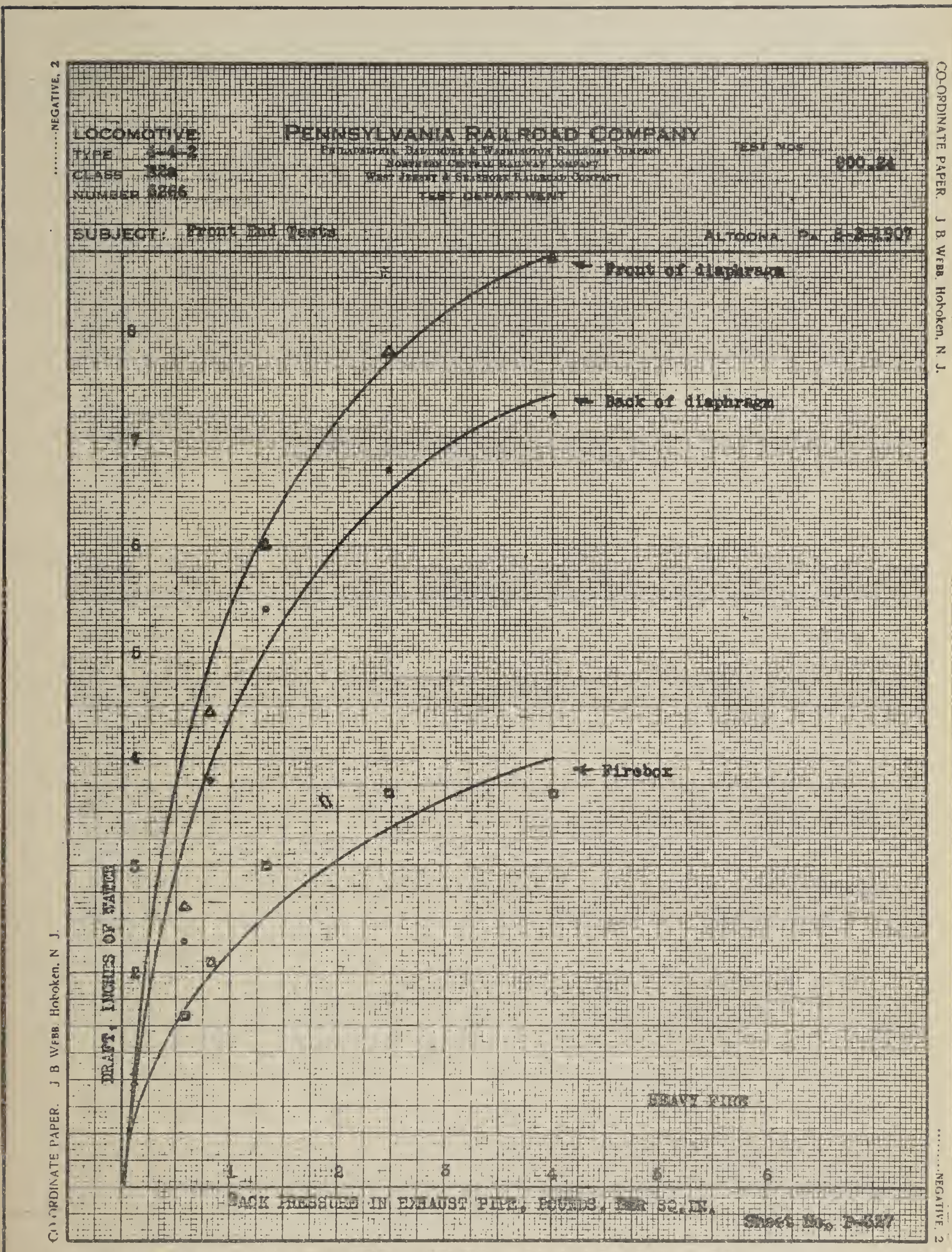


Fig. 5.

The draft in the smokebox and firebox with a thick or heavy fire. The draft is nearly two times what it was with a thin fire.

25. If the results with the standard front end could be equalled with a self-cleaning device the object of the tests would be accomplished, as, with the added advantage of a self-cleaning front, which would permit the use of friable coal, the capacity of the locomotive would not be reduced.

26. The tests were made with both Scalp Level and screened Penn Gas coals. The Scalp Level coal was used for the preliminary runs, as with it large quantities of cinders are drawn through the tubes and the self-cleaning feature could be better observed than with a coal making less cinders.

27. The final series of tests was made with Penn Gas coal as it is one of the regular passenger coals, while Scalp Level is not.

28. The same fireman fired all of the tests on locomotive 5266, with one exception, which will be noted later.

The Tests.

The Effect of a Movement of the Diaphragm Edge with the Standard Front End.

29. Before any changes were made in the standard front end, Fig. 2, some trials were made to note the effect on the fire of a movement of the lower edge of the diaphragm plate. The normal position of this edge for locomotive 5266 is as shown, $21\frac{1}{2}$ inches above the bottom of the smokebox. The plate was lowered $5\frac{1}{2}$ inches from this normal position and after a short trial run it was raised $5\frac{1}{4}$ inches above the normal position and a trial made.

30. These changes in the position of the diaphragm plate over a range of $10\frac{3}{4}$ inches, produced no marked effect upon the burning of the fire. It burned evenly over the whole grate under each adjustment of the diaphragm, and the locomotive steamed as freely with the plate in either the upper or the lower positions as it did under normal conditions.

31. The fact that the diaphragm is perforated may account for the lack of sensitiveness or marked effect upon the fire when the plate is given a new position.

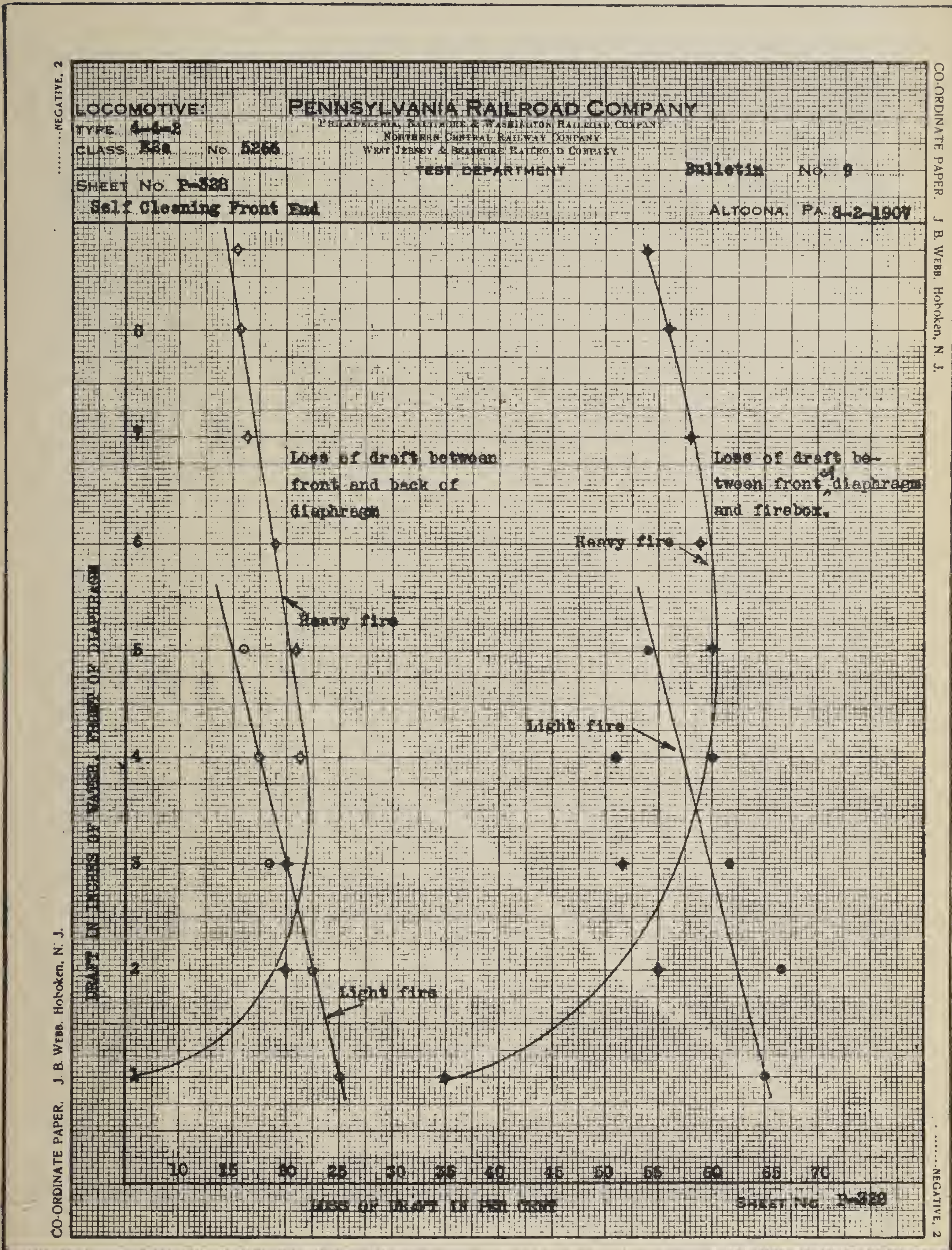


Fig. 6.

Draft losses at different rates of combustion with a thick and a thin fire. The loss in draft increases to a maximum, and then decreases with a thick fire. With the thin fire the losses become less as the draft Is increased.

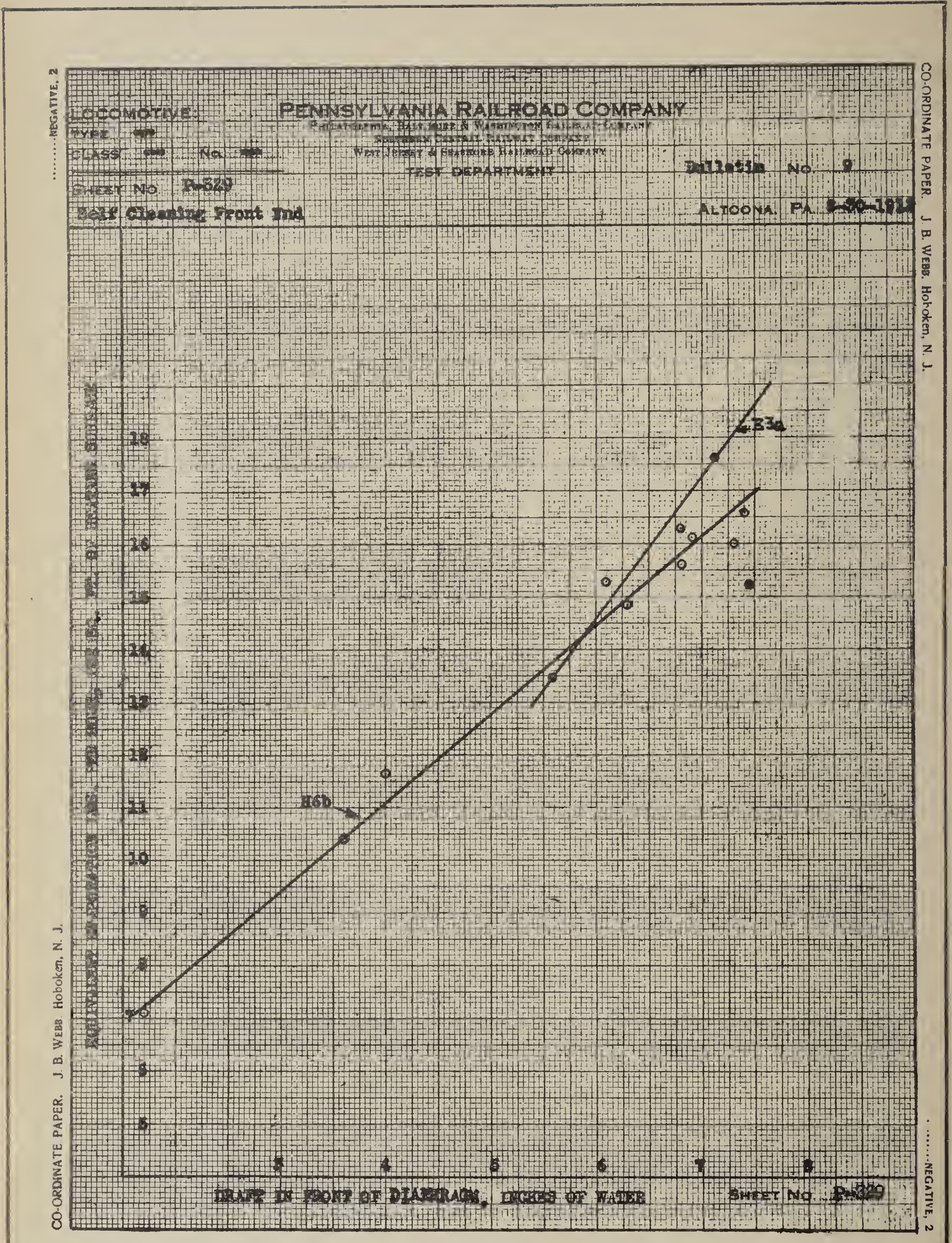


Fig. 7.

A comparison of draft and evaporation for the best arrangement on the E class and the H6b class. The rates of evaporation for the two classes are very nearly alike.

Preliminary Tests.

32. The trials of front end made by the Master Mechanics' Committee did not determine the arrangement of the diaphragm plate to make the smokebox self-cleaning, and the first consideration in these tests was to investigate the shape of the diaphragm and its location in the smokebox for this purpose.

33. A diaphragm of the general type recommended by the Committee as applied to this locomotive is shown in Fig. 8. The whole diaphragm plate was without perforation, and, as first applied, extended beyond the centre line of the nozzle a distance of 16¾ inches. At its end there was an angle and a plate 4¼ inches wide, extending downward to a point 13¼ inches above the bottom of the smokebox. The netting was omitted for these preliminary trials.

34. With the arrangement as described above and as shown in Fig. 8 a test was made, No. 900.25, using Scalp Level coal and working the boiler at about the limit of its capacity to maintain a good pressure. The arrangement was found to be perfectly self-cleaning, there being no cinders at all left in the bottom of the smokebox.

35. An inside stack, according to the Master Mechanics' recommendations, was then applied as shown in Fig. 9, and without other changes, a test, No. 900.26, was made at the same speed and cut-off as before.

36. The exhaust nozzle was then changed from 5⅝ inches diameter to 5⅞ inches diameter, but after a few minutes of running, with this large nozzle it was evident, on account of the falling pressure, that the nozzle was too large to give sufficient draft.

37. The nozzle was then reduced to 5¾ inches diameter, and without other changes a test was made at a lower rate of evaporation than the earlier tests.

38. This arrangement, Fig. 9, was found to steam fairly well and to be perfectly self-cleaning.

39. The smokebox was then fitted with a stack that was exactly according to the Master Mechanics' recommendations.

In tests Nos. 900.26, 900.27 and 900.28 the inside stack only had conformed to these recommendations. With this Master Mechanics' stack, which is shown in Fig. 10, tests with 5¾-inch and 5⅞-inch exhaust nozzle were made, tests Nos. 900.29, 900.30 and 900.31. In these tests it was observed that while the cinders were all blown out of the front end there appeared to be a higher velocity of the gases through the restricted passage under the edge of the diaphragm, than would be necessary for this purpose, or there was a large difference between the draft front and back of the diaphragm, indicating that too great a resistance to the passage of the gases was caused by the length of the diaphragm plate.

40. The plate was then cut off until it extended but 7½ inches in front of the exhaust nozzle centre.

41. Tests Nos. 900.32, 900.33 and 900.34 were then run and in the table below the resulting draft readings are given.

Table 1.

Draft in Front End—Scalp Level Coal.

Test No.	Test Designation			Front End Arrangement	Draft in Smokebox Inches of Water		Difference between F and B in Per Cent.	Diameter of Exhaust Nozzle	Back Pressure in Exhaust Pipe, Pounds per Square inch.	Cinders Collected in Smokebox, Pounds per Hour.
	M. P. H.	Cut-off	Throttle		Front of Diaphragm	Back of Diaphragm				
					F	B				
900.25	37.65	27	Full	Fig. 8	4.9	3.2	34.7	5⅝	4.6	0
900.26	37.65	27	Full	Fig. 6	4.8	3.3	37.5	5⅝	4.9	0
900.30	37.65	27	Full	Fig. 10	5.3	3.7	30.1	5¾	3.4	0
900.31	37.65	27	Full	Fig. 10	4.8	3.4	29.1	5⅞	2.4	0
900.32	37.65	27	Full	Fig. 10	5.2	4.3	17.3	5¾	4/6	48
900.34	37.65	27	Full	Fig. 10	5.0	4.3	16.0	5⅞	No record	No record
917	37.65	27	Full	Fig. 2	7.7	6.2	19.5	5⅝	No record	492

Tests 900.30 and 900.31 had the table plate extended 16½ in. ahead of the exhaust nozzle centre, while 900.32 and 900.34 had the plate 7¾ in. ahead of the nozzle.

42. While, in general, as has been explained, the draft indications can not be depended upon as comparative, it appears from these figures that when the diaphragm plate was shortened, just before test No. 900.32, that there was a

marked decrease in the difference between the draft front and back of the diaphragm, and that the effective draft, or the draft back of the diaphragm was increased.

43. Test No. 917 was with the same kind of coal as the others (Scalp Level), but with the old form or standard front end, Fig. 2.

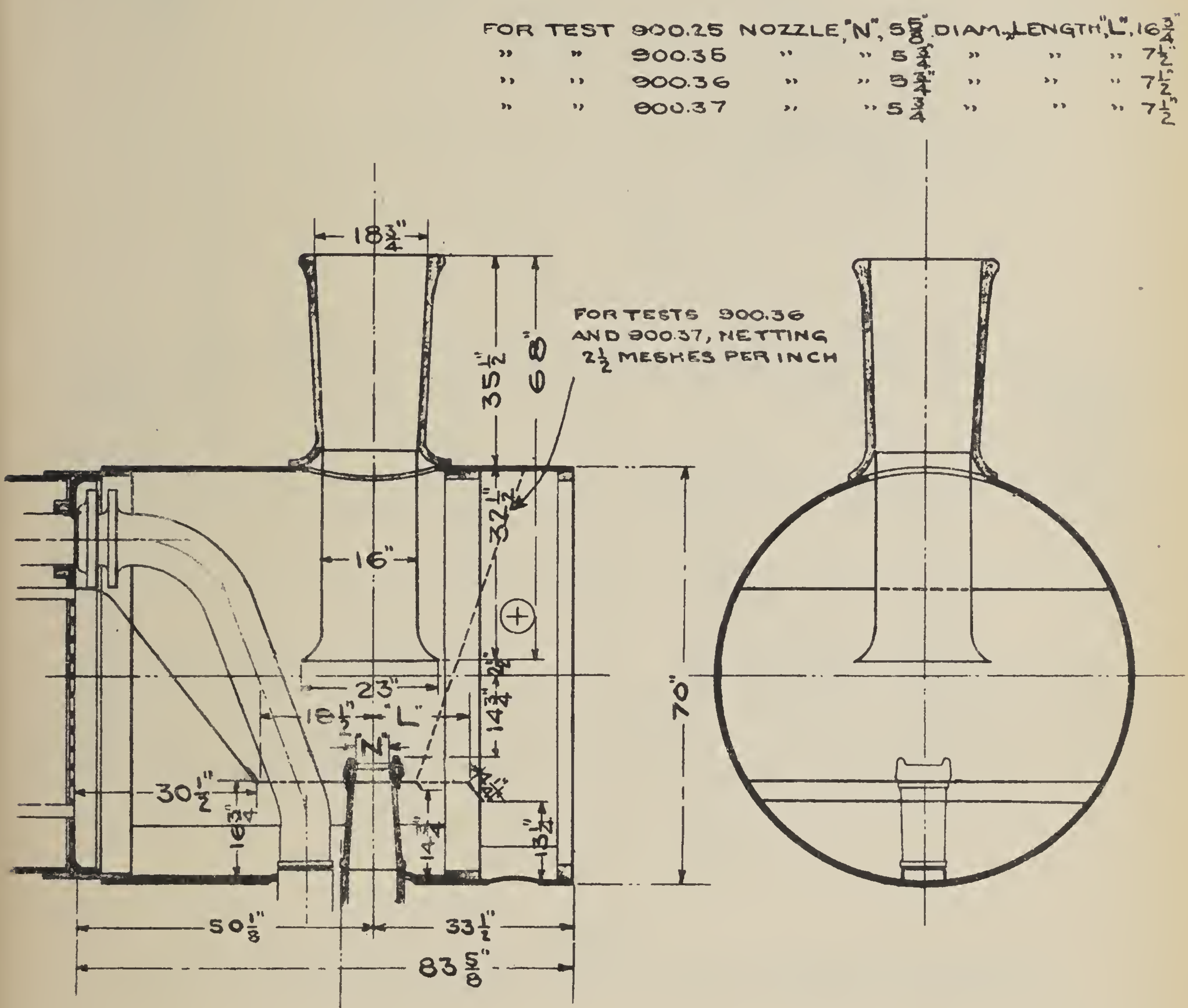


Fig. 8.

In this arrangement the diaphragm plate extends across the nozzle, and 16¾ inches ahead of it. After one test the plate was shortened to 7½ inches ahead of the nozzle.

44. In test No. 900.32 there were 48 pounds of cinders in the smokebox, indicating that the plate was now as short as it could be made for self-cleaning.

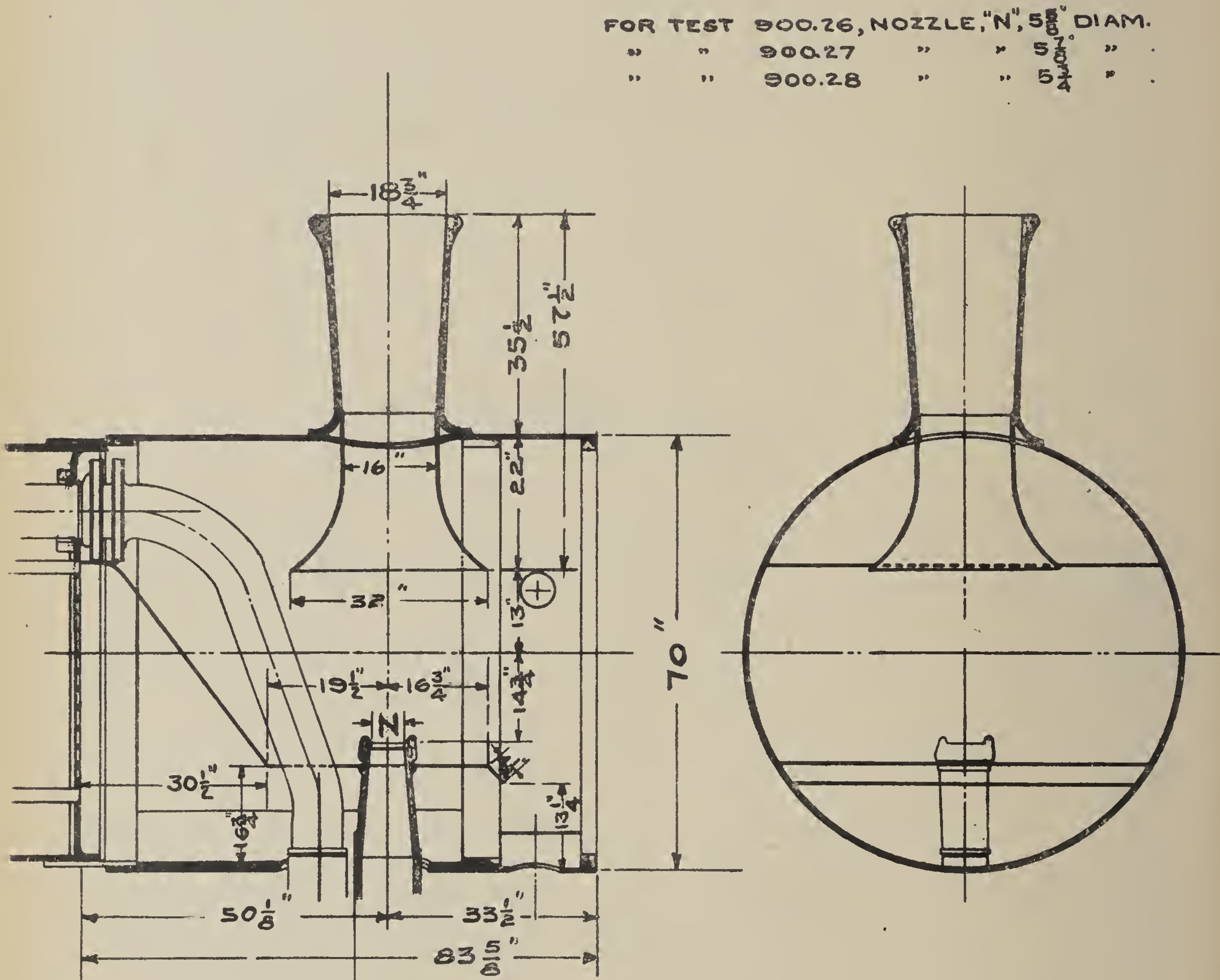


Fig. 9.

A new form of inside stack is applied. The long diaphragm plate is retained here. Three diameters of nozzle were used.

45. The smokebox arrangement was then made as shown in Fig. 8, the standard outside and inside stack being substituted for the Master Mechanics' form. A netting was put in with this arrangement.

46. Up to this time the netting had been omitted so as to simplify operations in making changes in the front end arrangement. It was assumed that the netting would have no effect upon the action of the front end, except to break up the large sparks, and this was confirmed later when the netting was applied.

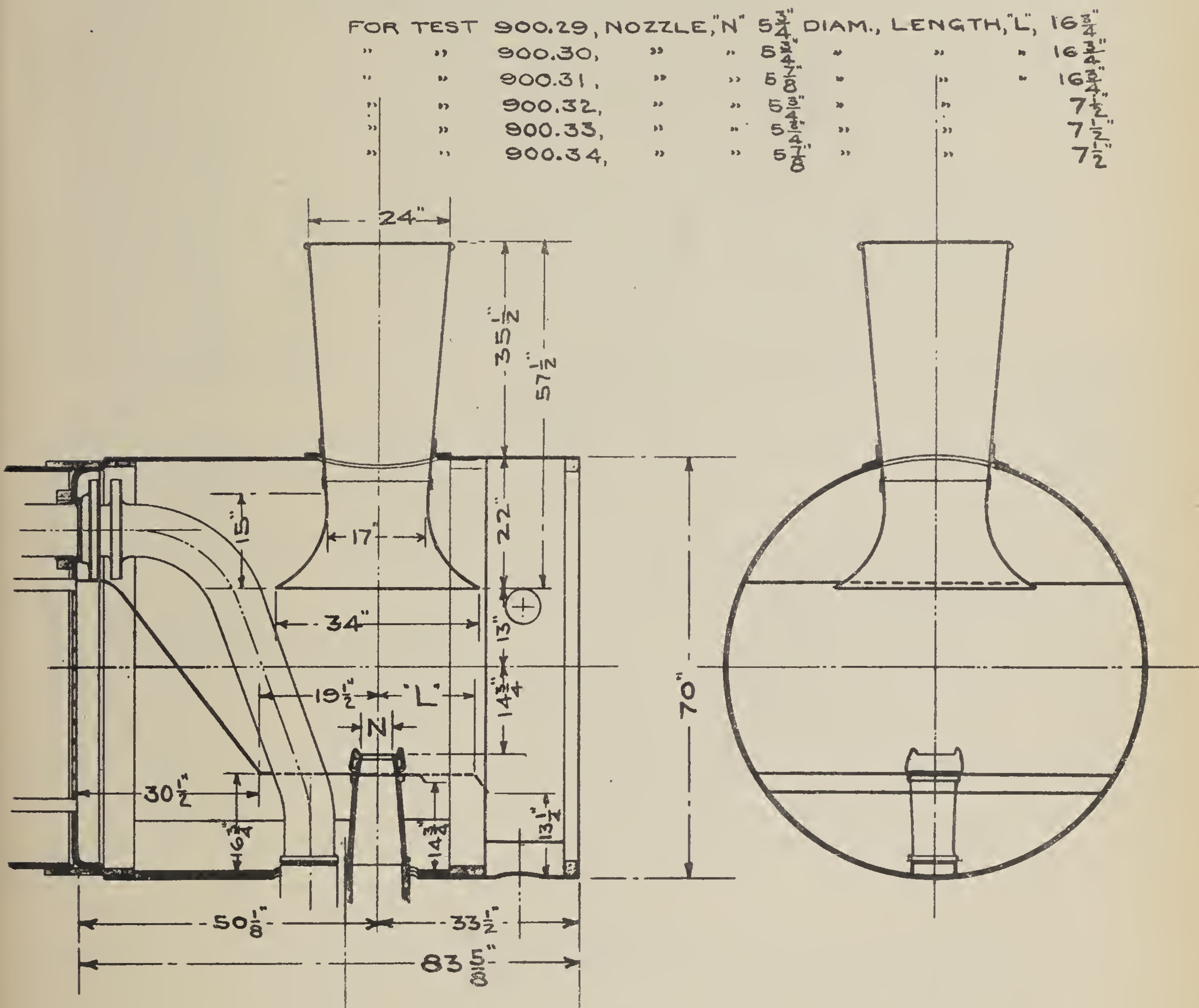


Fig. 10.

This shows the Master Mechanics' stack complete. Two lengths of diaphragm and two diameters of nozzle were used.

47. After making two tests, Nos. 900.36 and 900.37, with this arrangement the diaphragm plate was raised in the

smokebox as shown in Fig. 11, the exhaust nozzle being lengthened to suit the new height of diaphragm. At the front edge the plate measured 20½ inches above the bottom of the smokebox. With the diaphragm in this position the loco-

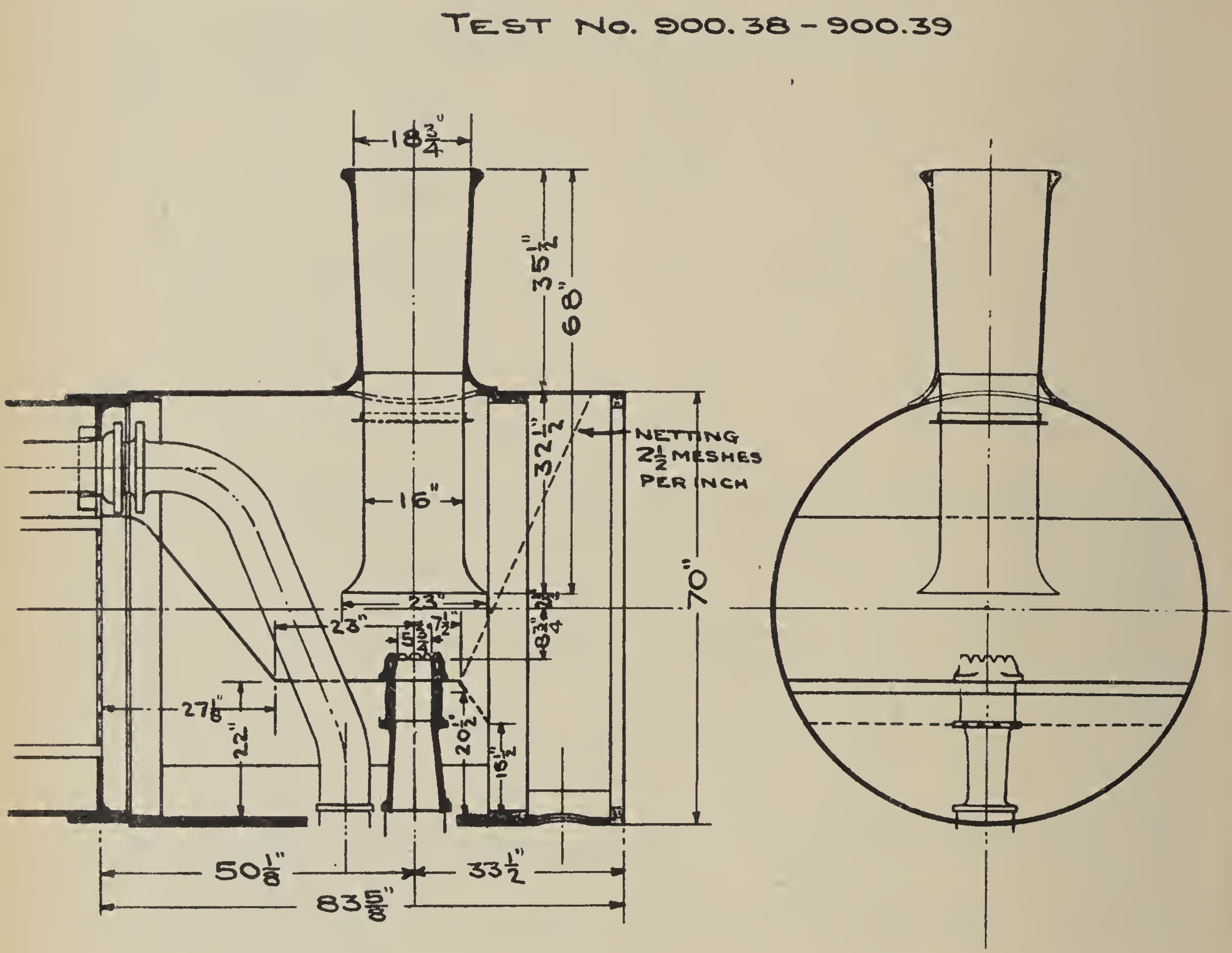


Fig. 11.
The standard stack has been returned to place, and the exhaust pipe lengthened.

motive steamed well—test No. 900.38—but there were 225 pounds of cinders collected in the smokebox per hour.

48. Without moving the main diaphragm plate, an inclined plate was fitted to its forward edge. This plate extended down to a point 15½ inches above the bottom of the smokebox. The area of opening for the passage of gases was then about

the same as in the arrangement shown in Fig. 8 and it was expected that the results would be the same as with the whole diaphragm in the lower position, but from the test, No. 900.39, with this design it is evident that the two arrangements, while giving the same area for the passage of gases, are by no means alike, as in test No. 900.39, the locomotive did not steam well and there were 76 pounds of cinders collected in the smokebox.

49. It would appear, then, that when changes are made in the height of diaphragm the whole plate should be raised and not the forward edge alone.

50. The plate without the movable deflector, presents, for the flow of gases, a passage free from obstructions or abrupt changes of form, and it is probable that this will account for the better results had with it than with the plate set high in the smokebox but having the movable edge plate.

51. Following still further the idea of making a smooth and direct passage for the gases to the stack, the arrangement shown in Fig. 12 was applied. This consists of a conical pipe from the tube sheet carried forward and turning upward and connecting at its smaller end directly to the stack.

52. The exhaust nozzle for this arrangement was made with a flared tip so that it would act as an expanding nozzle to convert the pressure energy of the steam into velocity, without loss, in that way obtaining an efficient exhaust jet.

53. Test No. 900.40 was made with this apparatus. It was very effective in discharging cinders, but the nozzle was found to be too large to make the locomotive steam. The sparks discharged from the stack were at a red heat and to break up these, and reduce their temperature, a netting was put in the pipe back of the exhaust nozzle and the nozzle reduced in diameter. The netting could not be very large in area on account of the limited space, and it was found that the area of the openings through it was too small for practical purposes.

54. Nothing further was done with this arrangement as it was not considered of value if a netting could not be used in it.

55. A diverging or flared tip nozzle was again tried with

the arrangement shown in Fig. 13. The smallest diameter of this nozzle was 5¾ inches, with a taper to the top of about one in six. The locomotive did not steam well with this nozzle, though the back pressure below the nozzle was reduced,

TEST No. 900.40

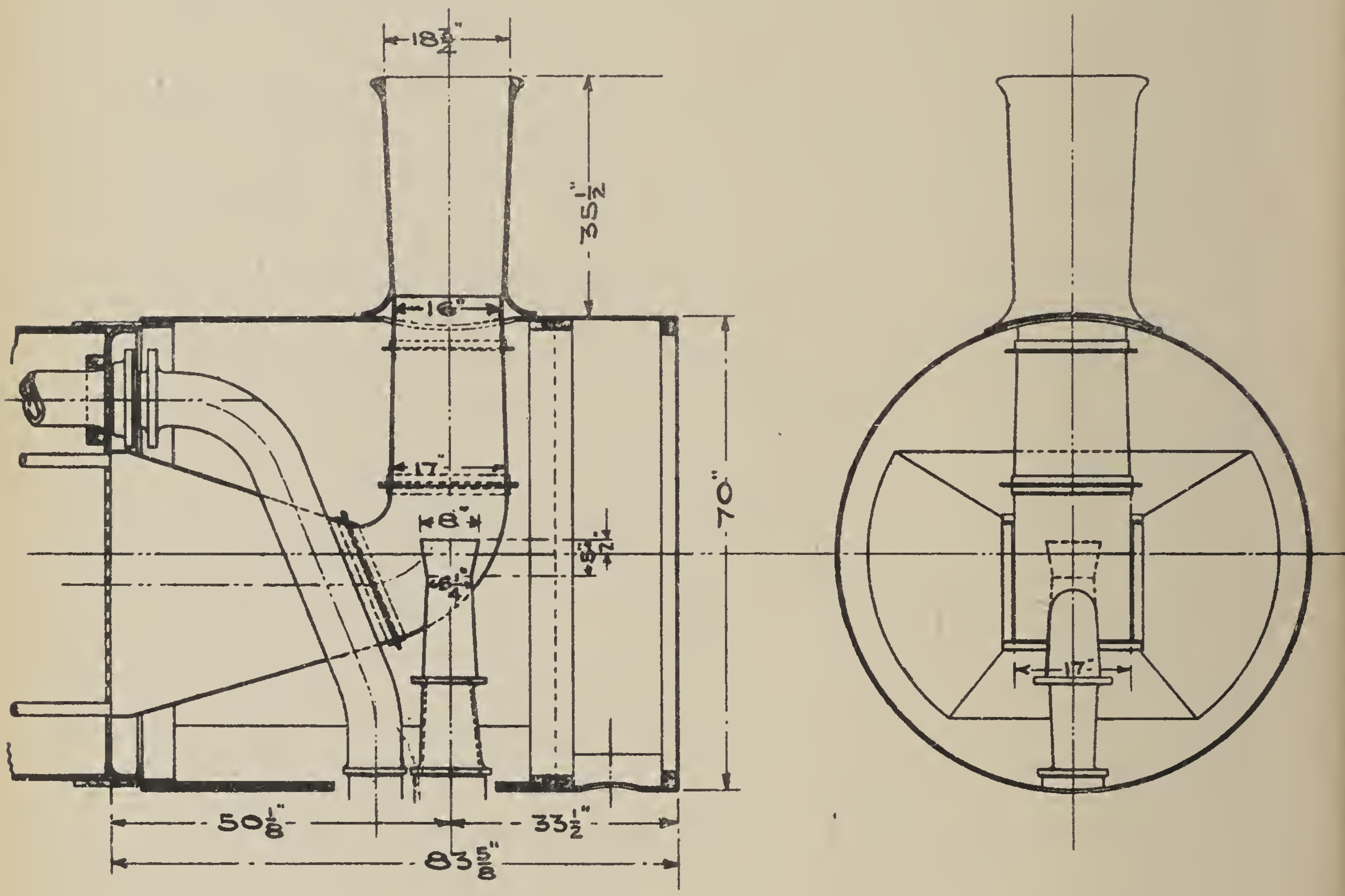


Fig. 12.

This is a tapered connection between the tubes and stack. It did not give satisfactory results.

test 900.47. With the straight nozzle, the back pressure was five pounds per square inch while with the tapered nozzle it was two pounds.

56. To make the locomotive steam it would have been necessary to further reduce the nozzle diameter, but as it was then as small as the straight nozzle it was not reduced and no further trials of it were made.

Final Tests.

57. After the preliminary trials of the various devices that have been described, three of those which were of greatest promise were selected for further tests. These arrangements are shown in Figs. 14, 15 and 16.

TEST No. 900.47

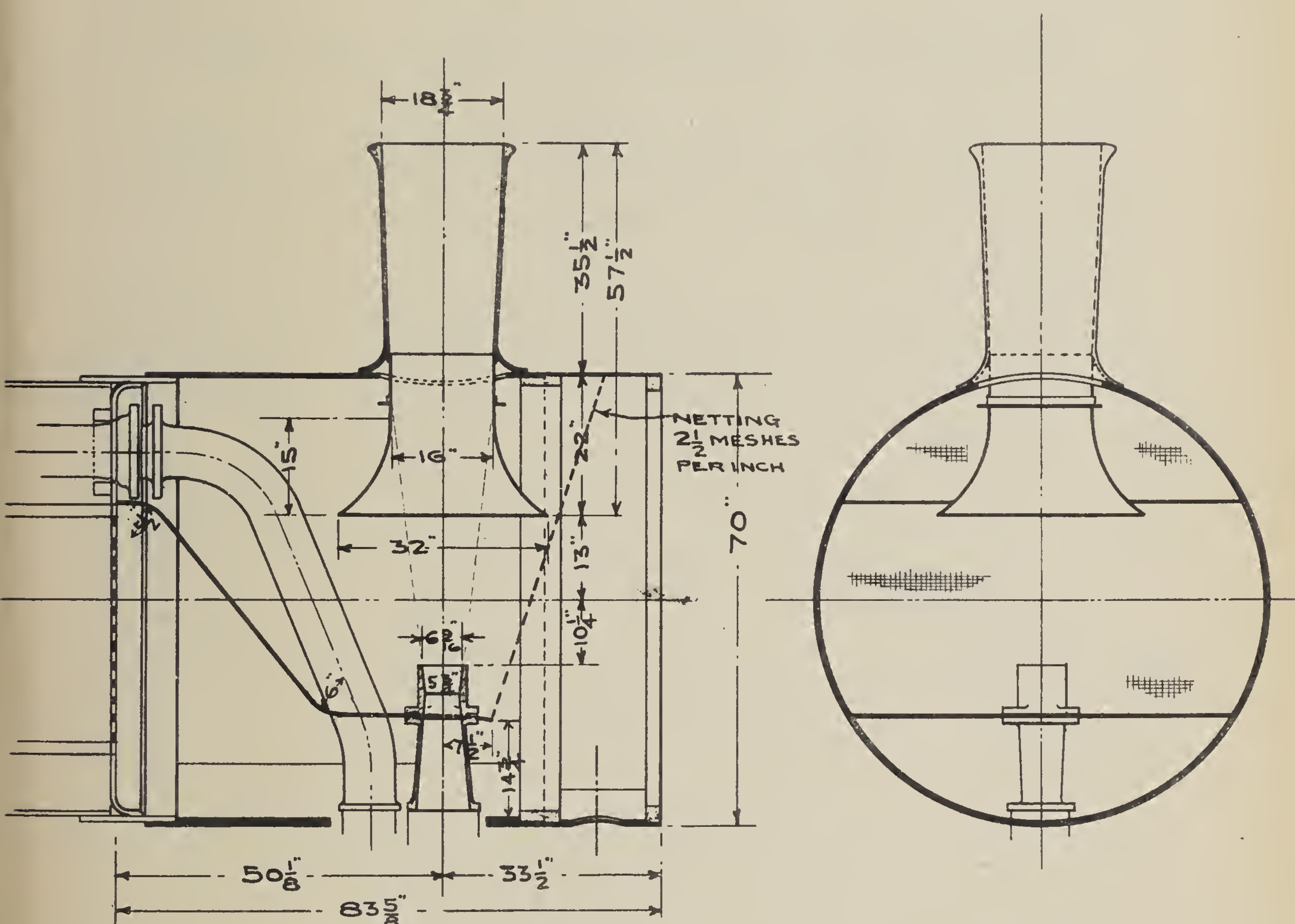


Fig. 13.
An expanding nozzle and the Master Mechanics' inside stack.

58. Fig. 14 shows the front end recommended by the Master Mechanics' Association as applied to the E class locomotive. It has a tapered stack with a wide-mouthed inside

stack. The diaphragm plate is without perforations and is carried down and forward to a point 7½ inches in front of the exhaust nozzle centre. The edge of the plate is at a point 14¾ inches above the bottom of the smokebox and the area of the passage for the gases at this restricted point is three-fourths of the area of the tube opening or fire area.

59. The tests with these three arrangements were each of two hours duration at 160 revolutions per minute, or about 36 miles per hour. Tests Nos. 900.41 to 900.44 were run at the same cut-off with full throttle. Penn Gas coal was used for all.

60. The results of these tests are given in the Tables 6 and 8.

61. Good results were obtained with each of these arrangements. They were all perfectly self-cleaning except for a slight accumulation of cinders on the horizontal plate of the diaphragm.

62. There was some difficulty in keeping up the steam with the arrangement Fig. 14, test No. 900.41, but it will be noted that the boiler horse-power in this test was higher than for the others.

63. Test No. 900.44, with arrangement Fig. 16, shows a better evaporation per pound of coal than any of the others and it was thought, all things considered, that this was the best arrangement.

64. Another test was then run with it to develop the maximum boiler capacity,—test No. 900.45 at 160 revolutions and 32 per cent. nominal cut-off, and this test was run without difficulty. This is as late a cut-off as can be run with the standard front end at this speed, and as with the arrangement, Fig. 16, the nozzle was ⅛ inch larger in diameter than was used with the standard arrangement, it is to be presumed that the boiler capacity is as great with this self-cleaning front as with the standard, with the added advantage of slightly decreased back pressure in the cylinders due to the large nozzle.

65. After the maximum capacity test a trial was made at a very low rate of working, under partial throttle, to note the effect of such conditions on the quantity of cinders collected in

the smokebox. This test, No. 900.46, at a speed of 160 revolutions, 27 per cent. cut-off and the steam throttled to one-half the boiler pressure, shows practically no cinders collected in the smokebox.

TESTS WITH DIFFERENT FIREMEN.

66. To show that the results obtained with this self-cleaning

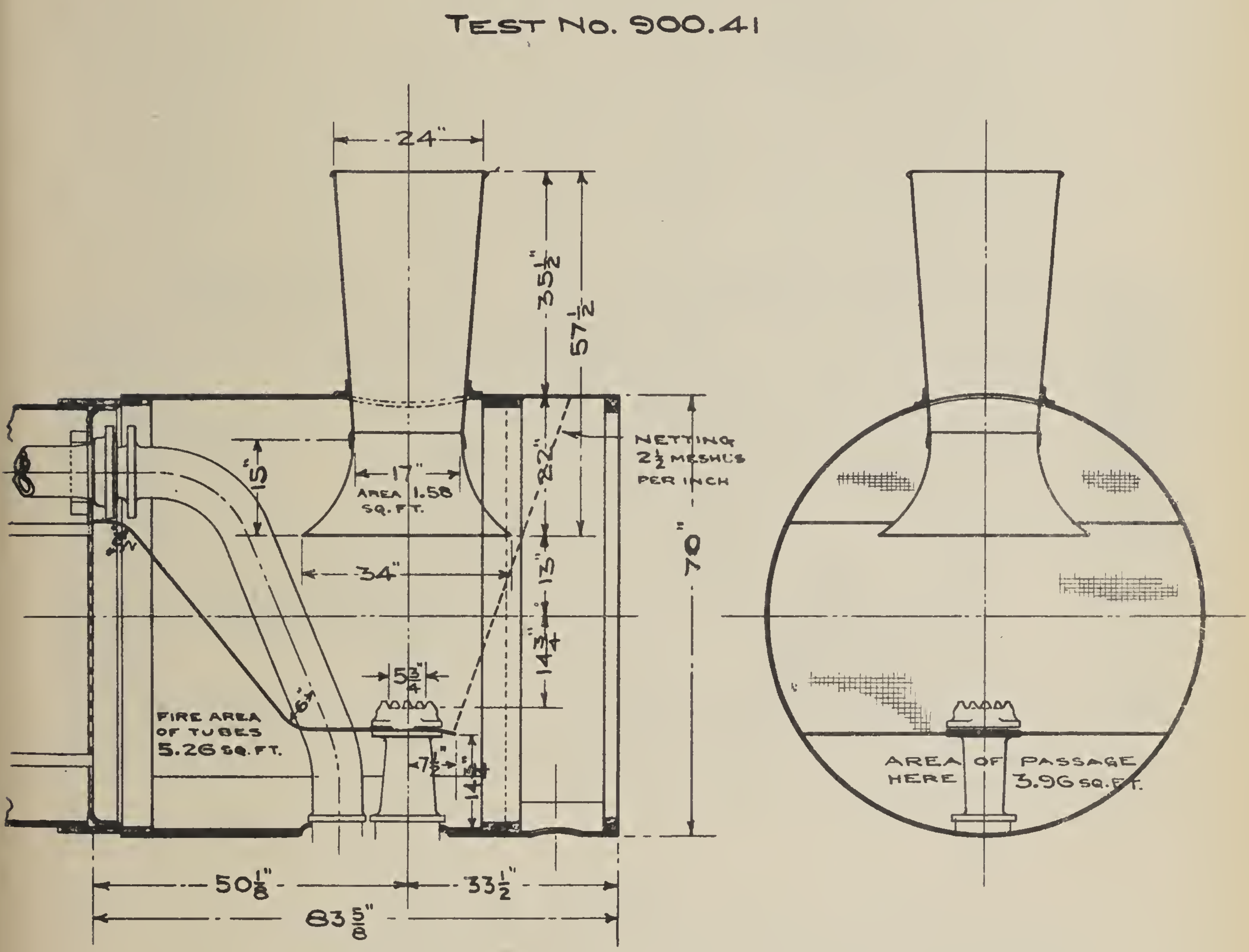


Fig. 14.
The Master Mechanics' stack. The length of front end does not conform to the Master Mechanics' recommendations.

front were not due to good firing alone, tests Nos. 900.42 and 900.43 with the arrangement shown in Fig. 15 were made under precisely the same conditions, with the exception that test No. 900.42 was fired by the regular Testing Plant fireman, while No.

900.43 was fired by an inexperienced man who had been firing but two months and had never fired this class of locomotive.

67. The results of these tests show that the good steaming of the locomotive with this self-cleaning front can be obtained by the average fireman, but they also show that the inexperienced

TEST No. 900.42 - 900.43

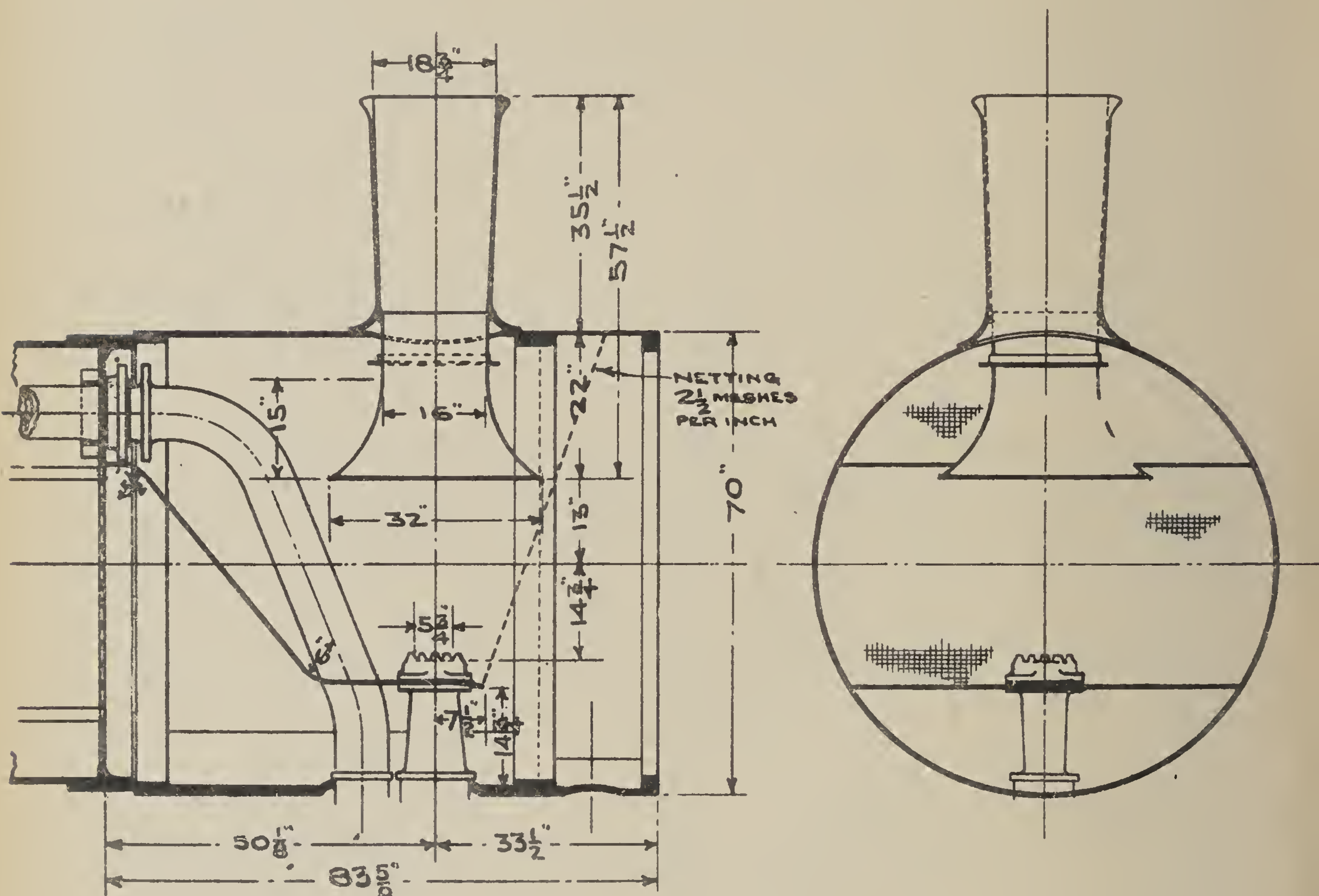


Fig. 15.
The Master Mechanics' inside stack and standard outside stack.

man may use as much as 750 pounds of coal per hour over the amount actually required.

Self-Cleaning Front E3a Class.

68. At this point, after tests which indicated that for locomotive 5266, E2a class, the self-cleaning front, Fig. 16 would give the best results, it was thought best to determine if this arrange-

ment would give equally good results if applied to another boiler of the same class. Locomotive 5266, class E2a was, therefore, removed from the plant and put into road service equipped with arrangement Fig. 16 and E3a locomotive 2984, fitted with the same arrangement, was placed on the plant.

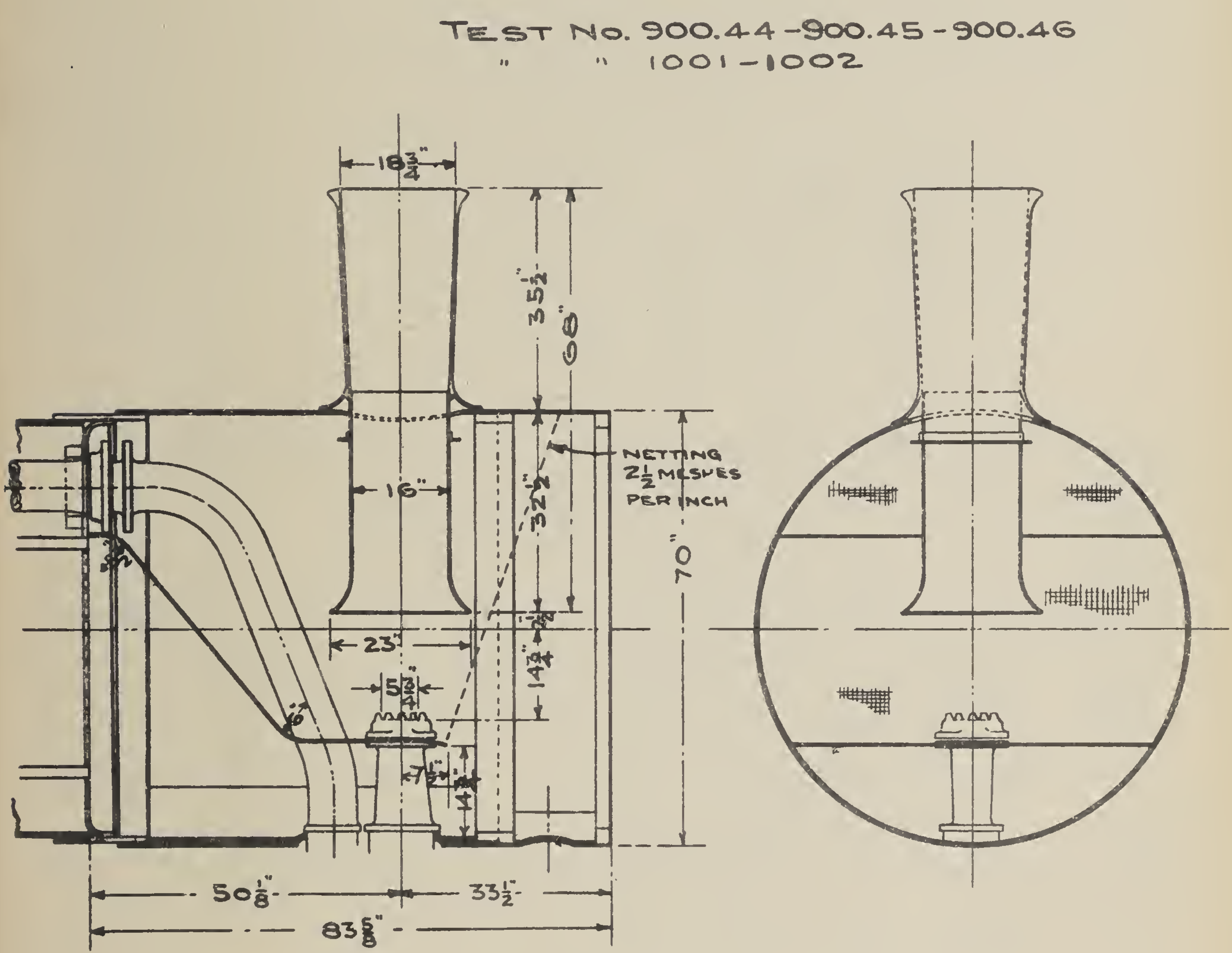


Fig. 16.

The standard stack and short form of diaphragm plate. This arrangement was satisfactory, except for cinders collecting on top of diaphragm.

69. Test No. 1001 with locomotive 2984 gave an evaporation (17.7 pounds per square foot of heating surface) that was practically the same as obtained with locomotive 5266, namely: 17.9 pounds equivalent evaporation per square foot of heating surface per hour. The locomotive steamed freely, maintaining a fairly

uniform boiler pressure and there were no cinders in the smoke-box except a small quantity on the horizontal plate of the diaphragm.

70. This test, No. 1001, did not appear to be quite up to the limit of boiler capacity, and had it been possible, the cut-off would

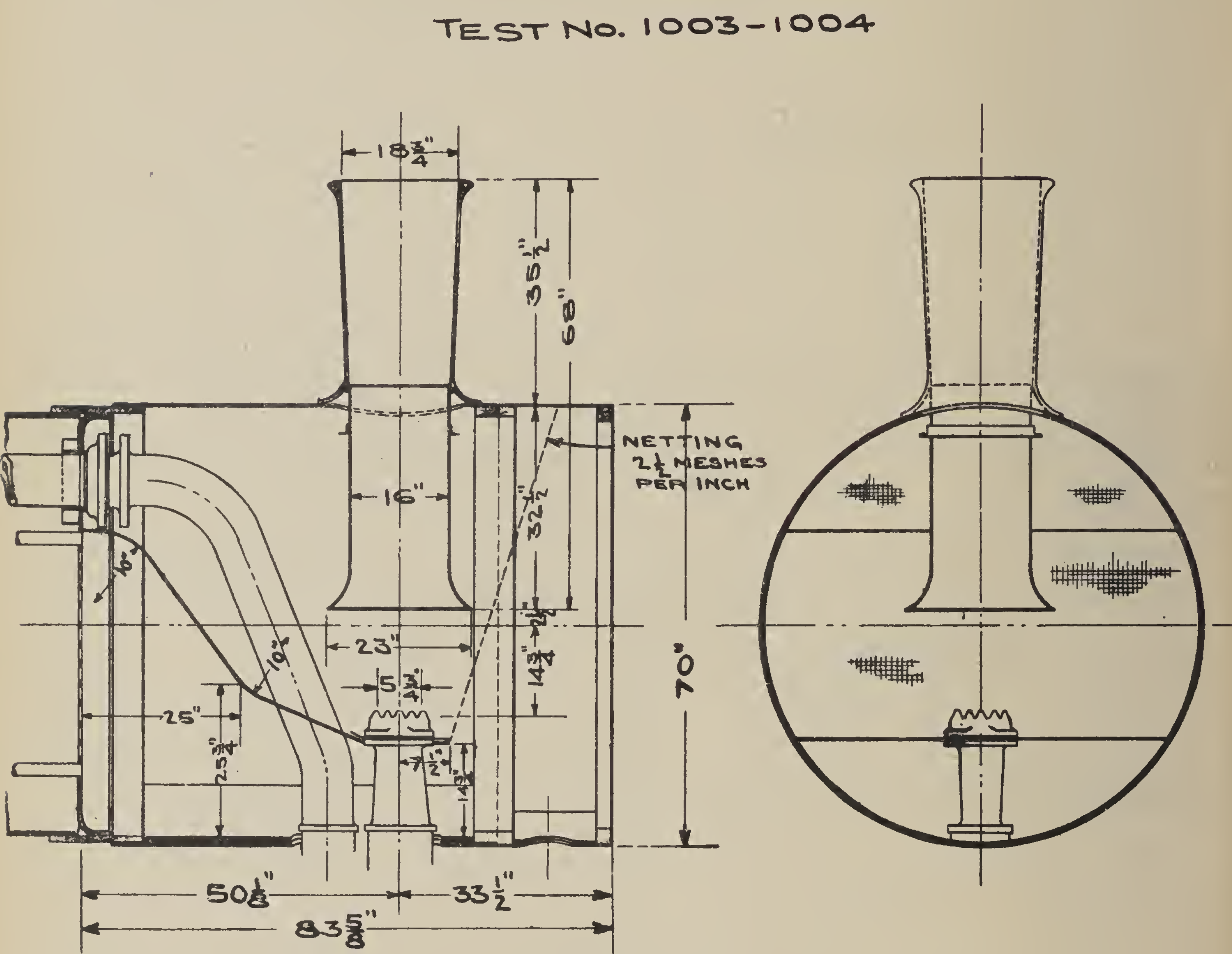


Fig. 17.
The diaphragm made sloping to remove cinders.

have been extended, but it was found for this locomotive that the friction brakes were working up to their limit and no more power could be absorbed by them.

71. Another test, No. 1003, was then made with this arrangement at slightly lower power.

72. From these two tests, though they were not quite up to

the maximum evaporation of the other locomotive, one of them was but two-tenths of a pound less per hour and it is clear that this boiler will give the same results as the other with this front end.

73. Modifications of the diaphragm were then taken up to

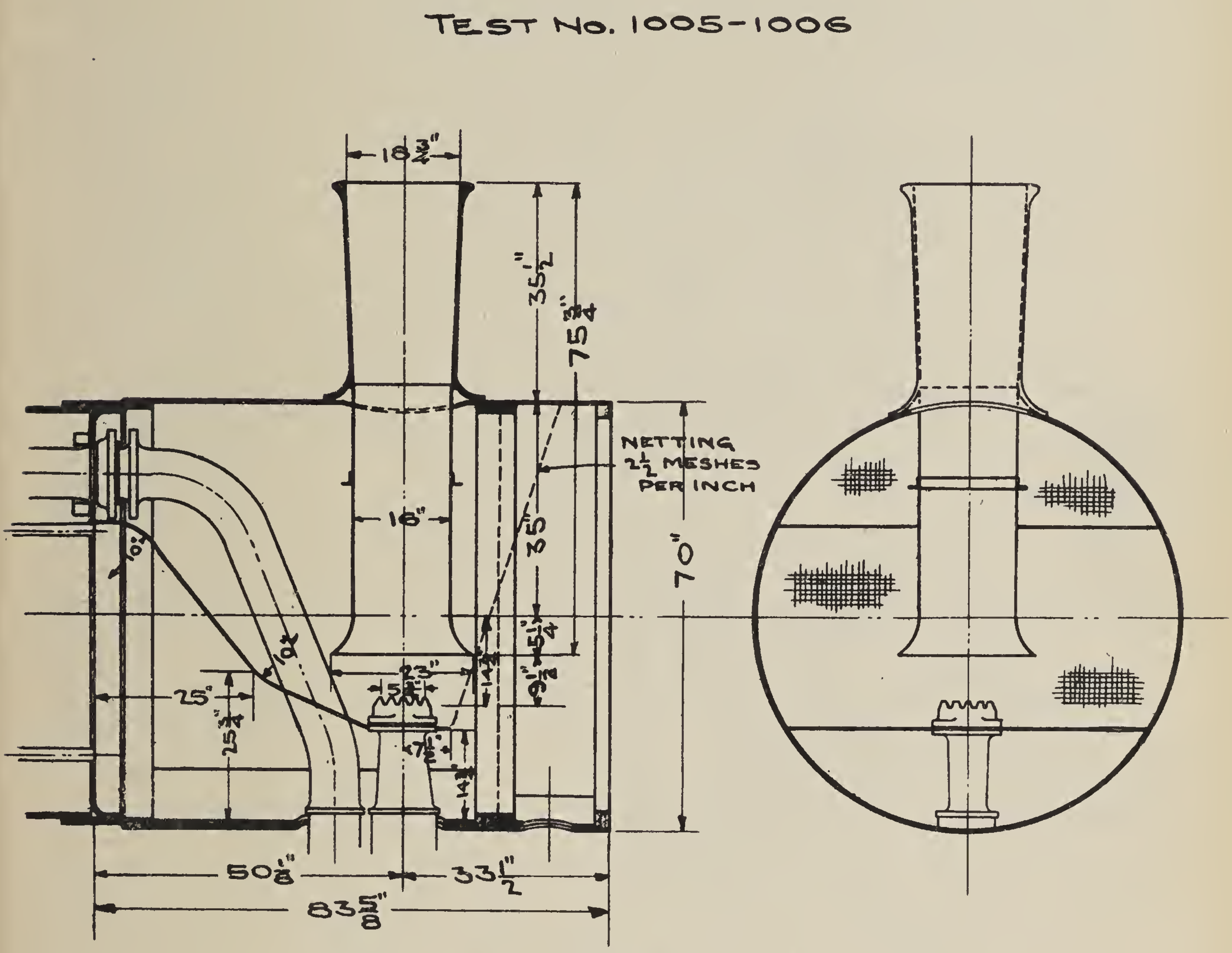


Fig. 18.
The inside stack lowered to clear cinders from plate. This lowering of the stack had the desired effect, but it was too low for good draft.

make it of such a shape that it would clear itself of the small quantity of cinders which had been collecting on it.

74. The plate was made sloping where in the earlier form it had been flat, just back of the exhaust nozzle. The sloping form is shown in Fig. 17. This modification of the form of the sheet

did not have the desired effect, for, in tests Nos. 1003 and 1004 with it, there was as large a quantity of cinders on the plate as before the change.

75. The inside stack was then lengthened as shown in Fig. 18

TEST No. 1007-1008

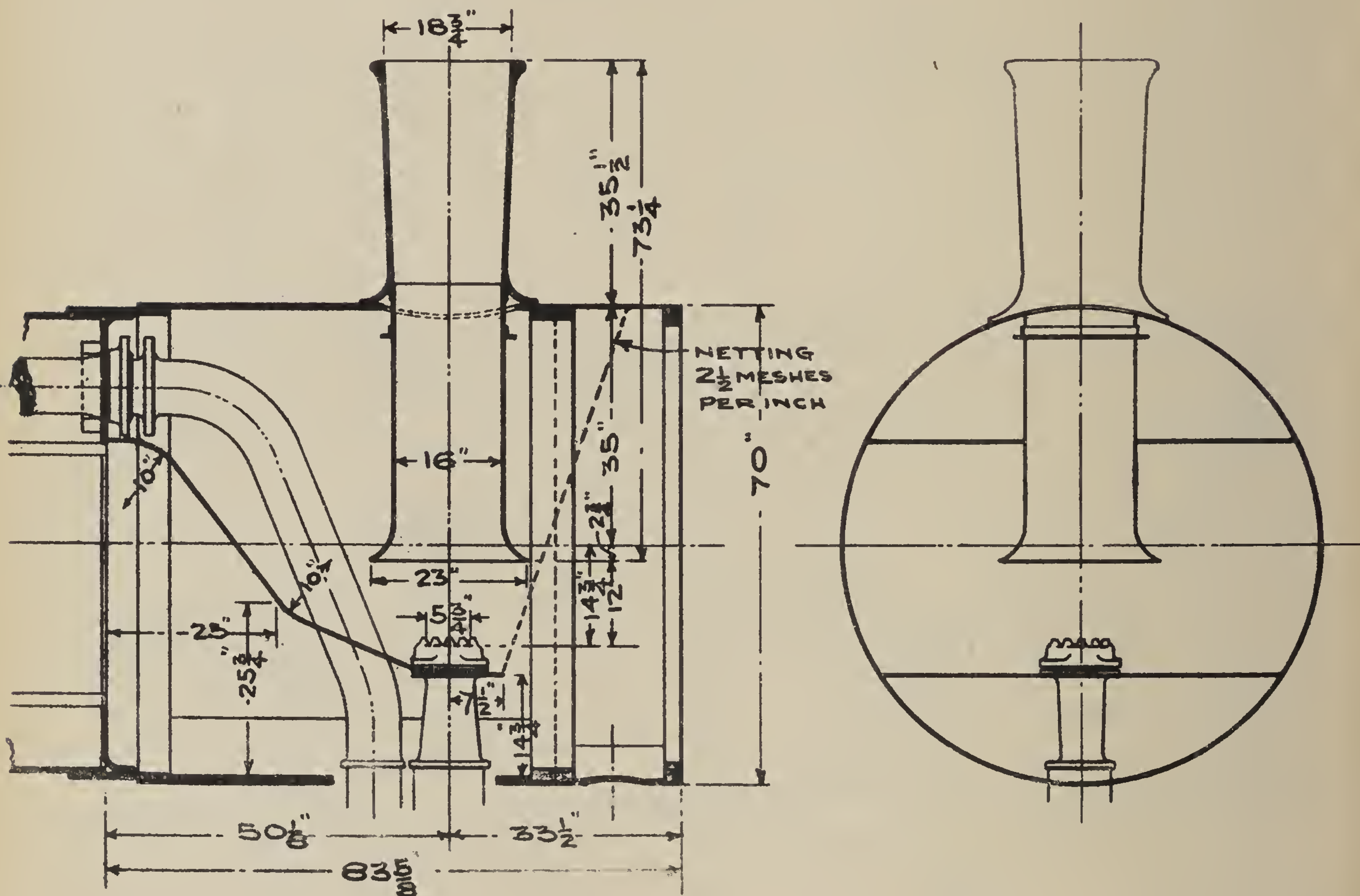


Fig. 19.

This arrangement is the final development of the front end for self-cleaning. The stack is the original standard for the E engines, except that the inside stack is longer. The diaphragm plate is without holes and extends 7½ inches ahead of the center of the nozzle. The fire area of the tubes is 5.26 sq. ft., and the opening for gases under the diaphragm is 3.96 sq. ft. or 75% of the fire area.

where the end of the stack is 9½ inches above the tip of the nozzle. This adjustment had the desired effect, and in tests Nos. 1005 and 1006 the cinders were practically all cleared from the plate.

76. The inside stack was then raised as in Fig. 19, to a point 12 inches above the nozzle, to find the highest position for

this inside stack that would clear the plate of cinders. Six shovelfulls of dry cinders were put on the plate and the locomotive run at a speed of about 120 revolutions and a short cut-off for about 15 minutes, when the cinders were all removed; next, six shovelfulls of wet cinders were put in and these were also cleared from the plate.

77. A test, No. 1007, was then made, using a slack coal of very small size, to note the effect of the self-cleaning feature. At the end of this test, there were a few pounds of cinders on the plate and very little in the bottom of the smokebox.

78. A test was then made, No. 1006, to observe if the capacity of the boiler had been reduced by the changes that had been made. This test gave an equivalent evaporation of 17.63 pounds per hour or practically the same as in test No. 1001, with the arrangement last tried on locomotive 5266.

79. Locomotive 2984 was then removed from the Plant and went into road service equipped with the device, Fig. 19, the final form, which satisfied the conditions of good steaming and self-cleaning.

Table 2.

Self-Cleaning Front Compared With Standard.

Test No.	Test Designation			Duration of Test Hours	Front End Arrangement	Boiler Pressure, Pounds per Square Inch	Evaporation, Dry Steam, per Square Foot of Heating Surface.	Pounds per Hour Equivalent Evaporation per Sq. Ft. of Heating Surface.	Equivalent Evaporation per Pound of Dry Coal	Coal per D. H. P. Hour, Pounds	Coal Fired	Cinders Collected in Smokebox, Pounds per Hour
	M. P. H.	Cut-off	Throttle									
917	37.65	27	Full	3	Fig. 2	188.4	12.24	15.00	7.25	....	Scalp Level	492
900.35	37.65	27	Full	1	Fig. 8	199.9	12.25	14.76	7.28	4.39	Scalp Level	10
900.36	37.65	27	Full	1	Fig. 8	198.6	12.09	14.54	7.87	4.13	Scalp Level	10
900.3	37.65	32	Full	2	Fig. 2	201.2	15.04	18.24	7.01	....	Penn Gas	326
900.37	37.65	32	Full	1	Fig. 8	204.1	15.08	18.17	7.39	4.66	Penn Gas	6
900.45	37.65	32	Full	2	Fig. 16	199.5	14.80	17.89	8.65	4.00	Penn Gas	0
1001	46.27	25	Full	1	Fig. 16	199.6	14.55	17.73	7.33	4.30	Penn Gas	0
1008	46.27	25	Full	1	Fig. 19	202.7	14.38	17.63	8.15	4.02	Penn Gas	0

80. In Table 2, some of the results of the tests of the final form of the self-cleaning front are shown in comparison with the standard front. The tests are in two groups, those with Scalp Level coal being made at a shorter cut-off and lower evaporation than those with Penn Gas coal.

THE H6b CLASS CONSOLIDATION TYPE LOCOMOTIVE.
The type of locomotive used in the Front End tests.

SELF-CLEANING FRONT END FOR CLASS H6b LOCOMOTIVE.

Conclusions and Recommendations on page 53.

INTRODUCTION.

81. The H6 consolidation locomotive on the Lines West has had for some time a self-cleaning front end which is very much like that developed for the E class, and a number of locomotives were equipped with the device.

82. Several other front end arrangements were in use at different places on the Lines East, and in order to determine the relative merits of these devices, in discharging cinders, a series of trials were made on the Locomotive Testing Plant. The locomotive used, was an H6b class, No. 2860.

83. As the trials were made to determine the relative merits of the several devices, each separate device was not taken up and developed, as may have been possible, so that it would give satisfactory results. The tests are comparative, as nearly as they could be made, and the same kind of coal was used in all of them. As the result of these trials with the freight locomotive, a satisfactory self-cleaning front end was found in the arrangement as shown in Fig. 25.

THE STANDARD FRONT END.

84. The H6b locomotive when designed, had a front end arrangement, as shown in Fig. 20, and this has been a standard on both the H6a and H6b classes. It is in no sense a self-cleaning front end, although some sparks are discharged. A large amount, however, collect in the smokebox and must be removed at the end of each trip.

85. This standard front end has a deflector plate in front of the tube sheet, the purpose of which, is to restrict the draft through the upper rows of tubes where the velocity of the gases is too great, unless a dampening action is introduced by means of such a flat deflector.

86. Automatic cleaning of the front end is accomplished, as has been explained in the former chapter, by creating a rapid motion of the gases through the smokebox by restricting the area of the passage below the diaphragm plate.

Front End with Baffle Plate.

87. One means of creating this rapid flow of gases has been tried on the Lines East with an arrangement like that shown in Fig. 22, this arrangement has an inclined plate covering the whole area of the smokebox at the front end, and the gases, flowing under the edge of the deflector plate, are somewhat restricted by this baffle plate and sparks are carried out of the stack.

The B. & A. V. or Buffalo Self-Cleaning Front End.

88. The front end arrangement shown in Fig. 23 is one that has been in use on the B. & A. Division. It is not unlike the front end developed for the E class, but it differs in having a high exhaust pipe, with the nozzle set high in the smokebox.

Erie Division or Sunbury Self-Cleaning Front End.

89. A self-cleaning front end, developed and used on the Erie Division, is shown in Fig. 24. This has the high exhaust pipe as in Fig. 23, and in addition it has a more complete diaphragm plate, with an inclined front edge. Instead of the inside stack, as in the other front end, this one has two "petticoat" pipes with an opening between the top one and the stack base.

Self-Cleaning Front End as Designed and Used on The Lines West.

90. This front end, Fig. 25, is much like the design worked out for the E class passenger locomotive but adapted to the H6b class. It has a solid diaphragm plate, extending from the tube sheet, downward and forward across the exhaust nozzle, which is set low in the smokebox. The edge of the plate is $6\frac{3}{4}$ inches in front of the exhaust nozzle centre. The inside stack, or lift pipe, is extended to a point $15\frac{1}{4}$ inches above the exhaust nozzle.

91. Each of these arrangements was in turn applied to an H6b class locomotive, and a series of trial runs made. The front ends which gave poor results were not further adjusted, but the

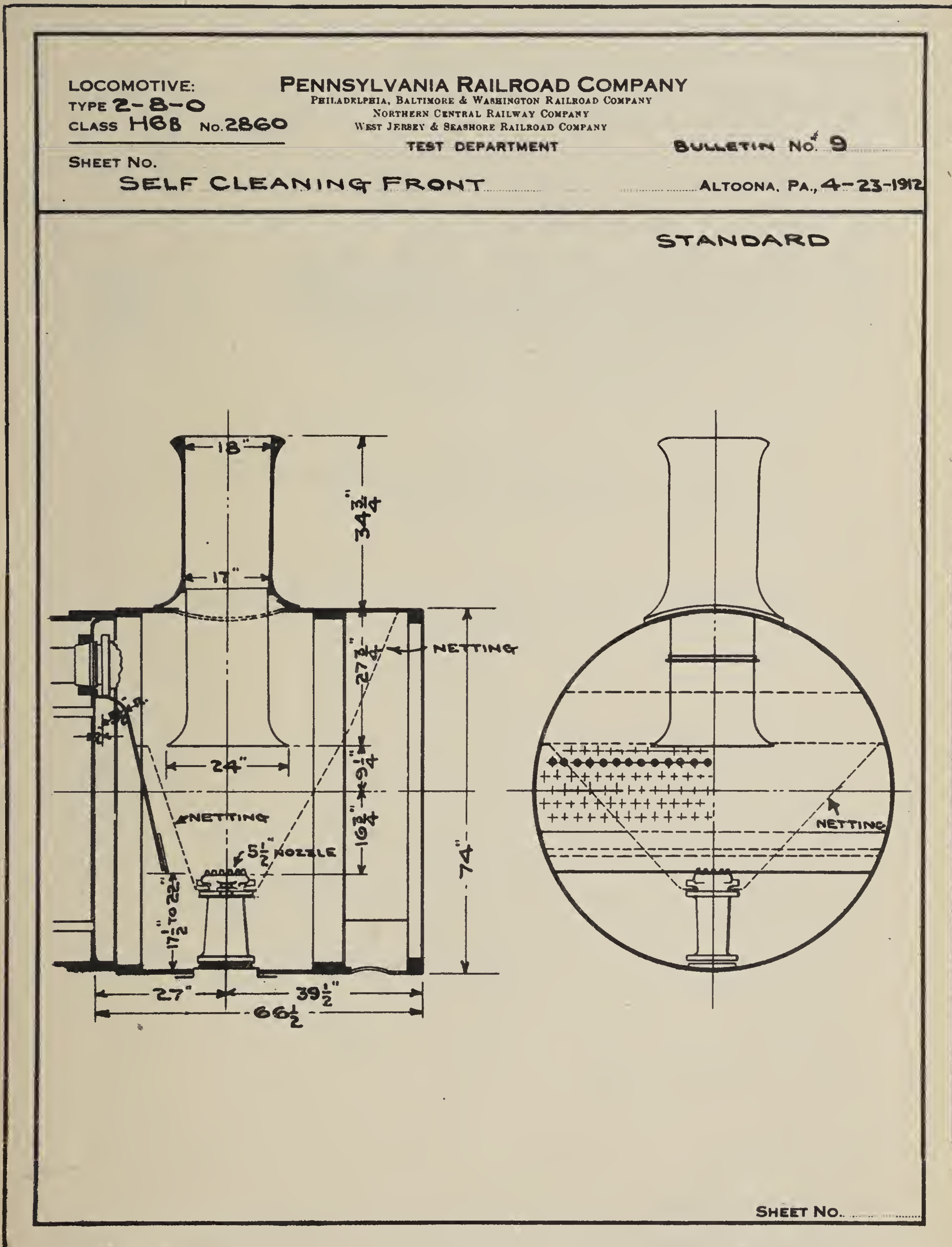


Fig. 20.

The standard front end arrangement for the H6b freight locomotive. There is a perforated deflector in front of the tube sheet. This deflector has an adjustable edge. A netting covers the holes in the deflector plate. This arrangement is not self-cleaning and the cinders must be taken out after each trip.

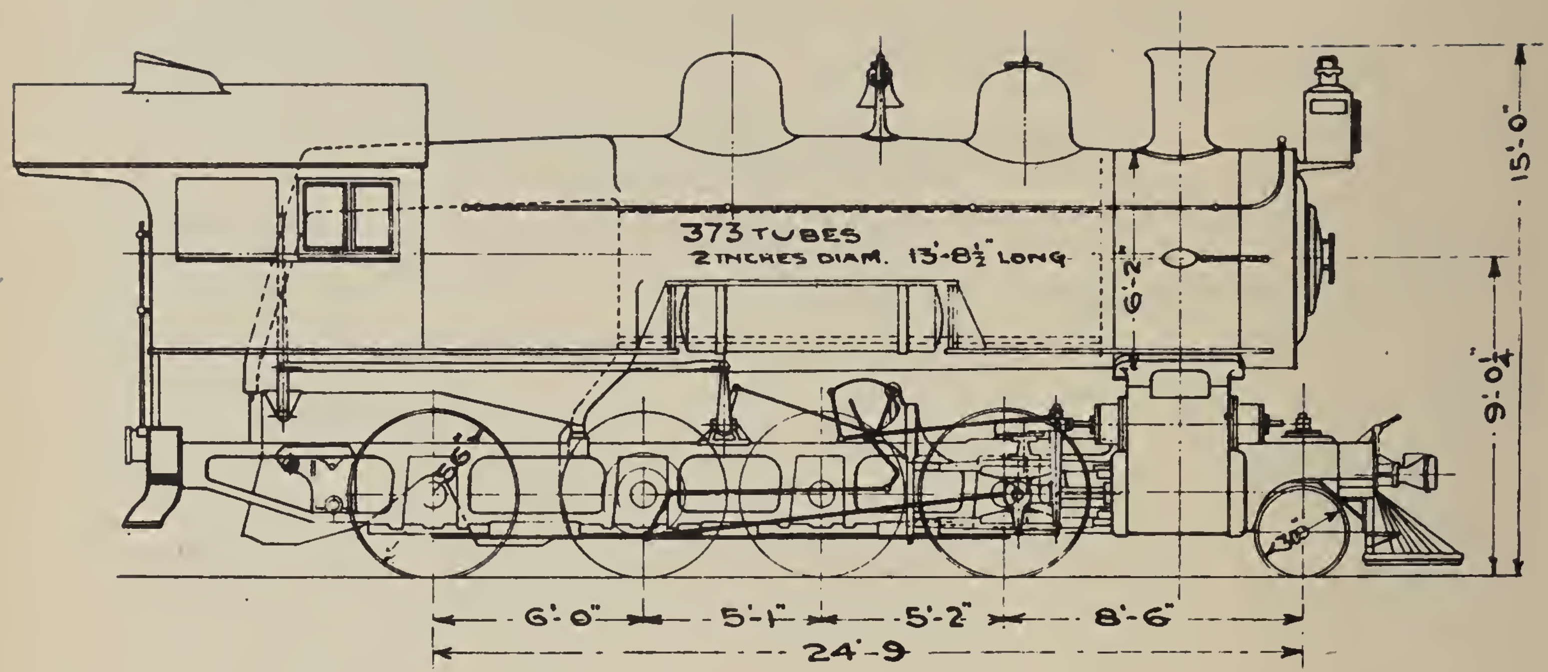


Fig. 21.
GENERAL ARRANGEMENT OF H6b CLASS LOCOMOTIVE.
The Locomotive used in the Tests.

LEADING DIMENSIONS OF LOCOMOTIVE (H6b CLASS)

Total weight, pounds	198,267
Weight on drivers, pounds	176,600
Cylinders (simple), inches	22x28
Diameter of drivers, inches	56
Fire-box heating surface, square feet	166.4
Heating surface in tubes (water side), square feet	2,673.68
Total heating surface (based on water side of tubes), square feet	2,839.74
Total heating surface (based on fire side of tubes), square feet	2,505.29
Grate area, square feet	48.66
Boiler pressure, pounds	205
Valves	Piston
Valve motion	Walschaerts
Fire-box, type	Belpaire
Number of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.28

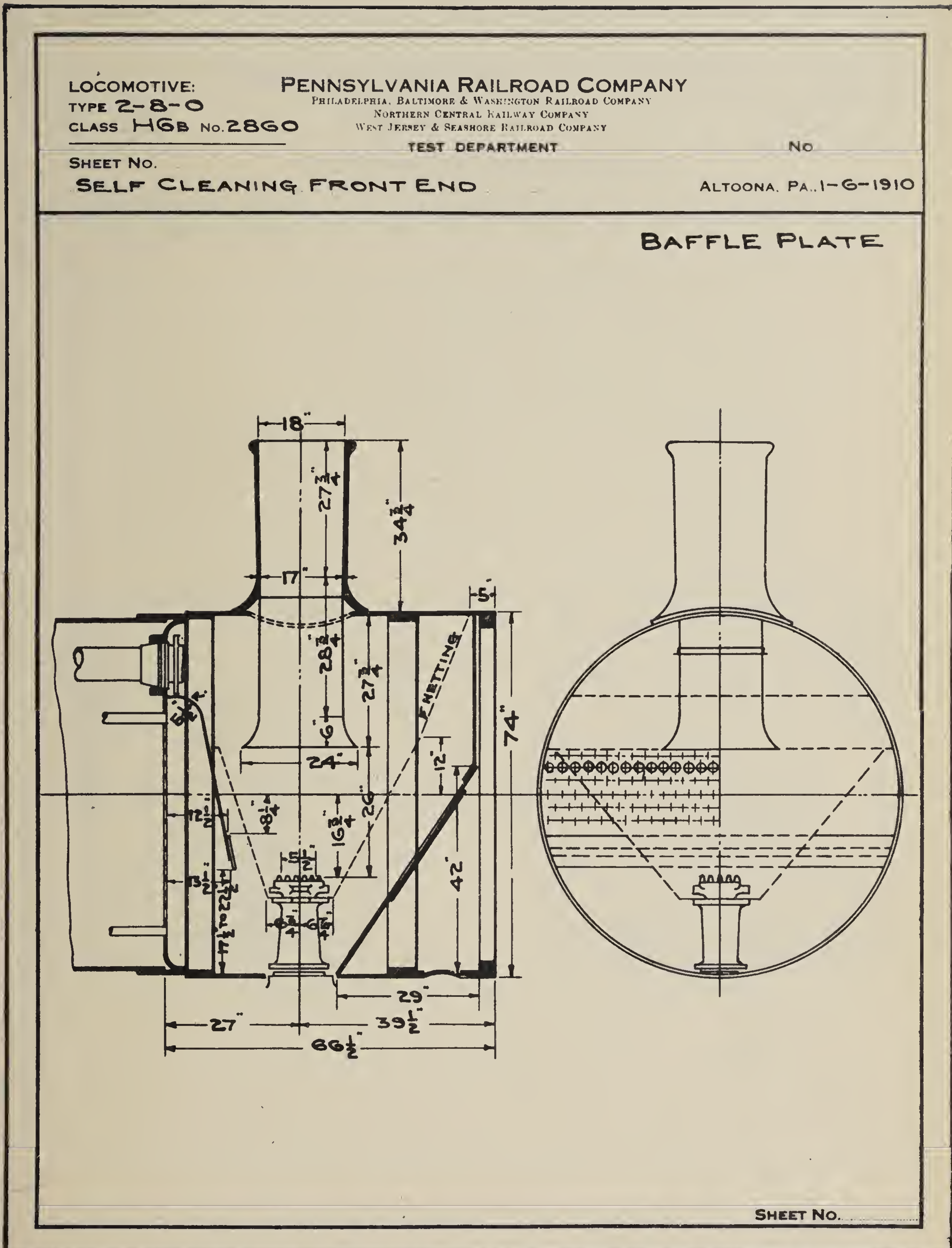


Fig. 22.

Front end with baffle plate. This front end is the same as Fig. 20, but with a plate added covering the whole area of the smokebox in front of the exhaust nozzle. The plate makes the front self-cleaning.

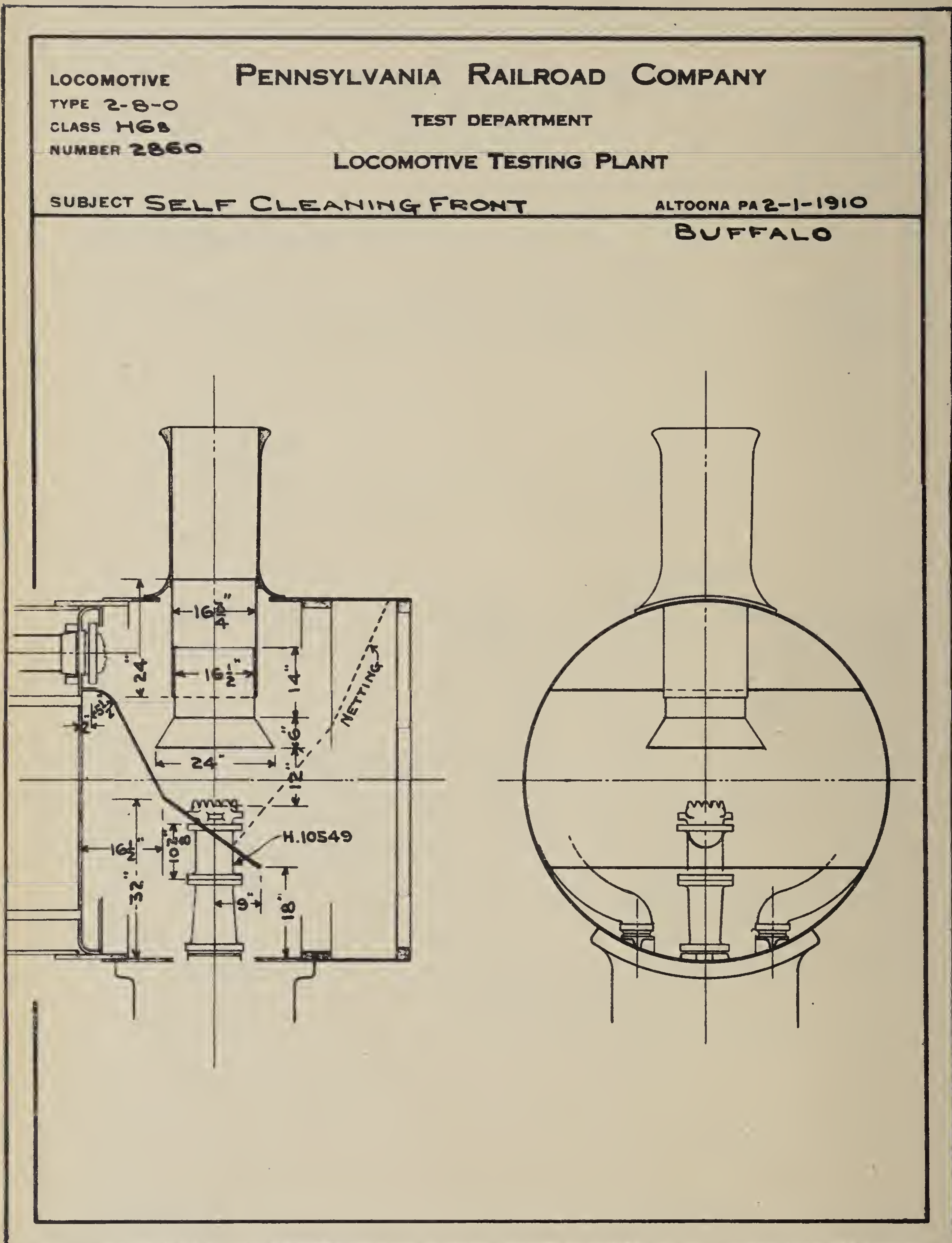


Fig. 23.
A front end arrangement developed and used on the B. & A. V. Division.

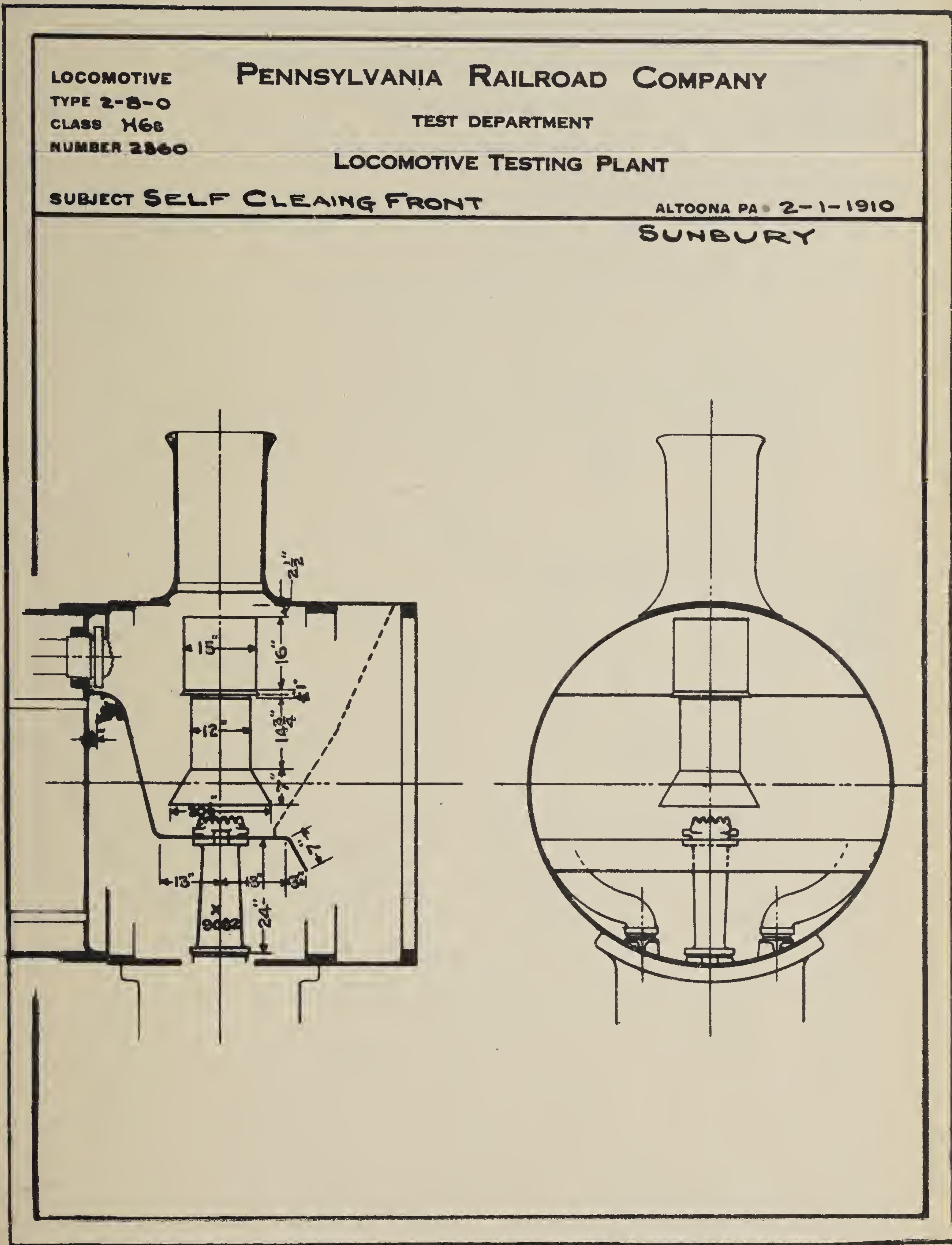


Fig. 24.
A front end arrangement developed and used on the Erie Division.

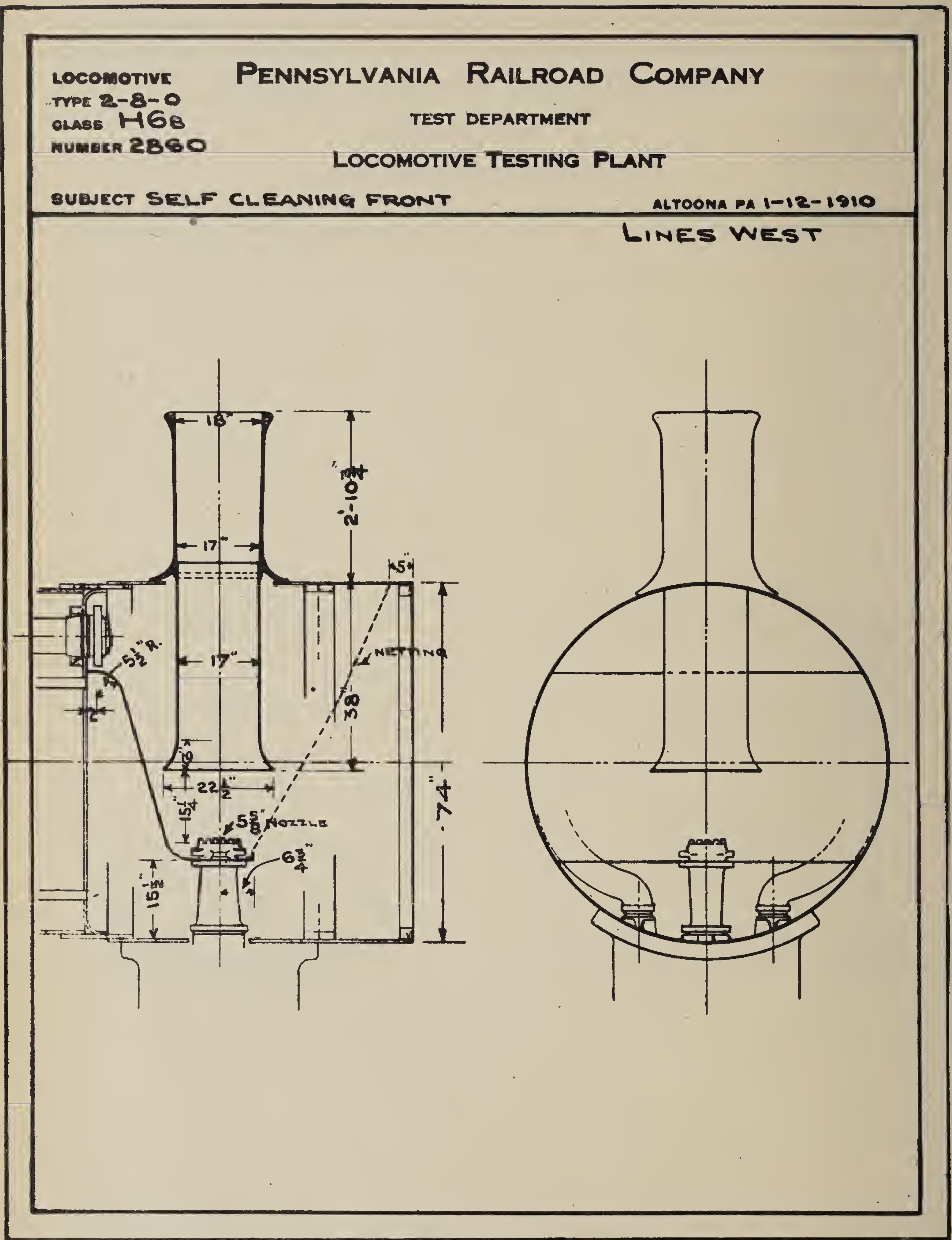


Fig. 25.

A front end arrangement developed and used on the Lines West. This arrangement is simple and easily applied. It gave the best results of any tested.

results were accepted as showing the general performance of the front end being tried. No efficient means of collecting the cinders discharged from the stack was available at the time of the tests, so the only measurement of cinders that could be made was of those remaining in the smokebox.

92. The coal used was Jamison run-of-mine, a high volatile coal which has been used to a considerable extent on the Locomotive Testing Plant with this class of locomotive. It is a bituminous coal of fair quality and contains a considerable amount of small size material, which is discharged as sparks. It is not, however, in this respect, like the low volatile friable coals which form a much larger quantity of sparks.

93. Five or more tests, from one to two hours each, were run with each front end, and the results are shown in Tables 10 to 14. A general summary of the results for a test at about the maximum evaporation for each of the front ends is shown in Table 15.

Table 15.

Front End Arrangement	Test No.	Test Designation			Average Boiler Pressure	Actual Evaporation of Water per Hour	Equivalent Evaporation per Square Foot of Heating Surface.	Draft in Smokebox Inches of Water		Dry Coal, Pounds per D. H. P.	Cinders Collected in Smokebox, Pounds per Hour
		M. P. H.	Cut-off	Throttle				Front of Diaphragm	Back of Diaphragm		
Fig. 25...	1200.446	19.2	45	F	204.9	33722	16.4	6.8	4.9	5.37	17
Fig. 22...	1200.427	19.3	45	F	201.6	32438	15.8	5.7	5.1	4.87	29
Fig. 23...	1200.448	19.2	45	F	188.3	31208	15.2	5.1	4.9	5.56	136
Fig. 24...	1200.440	19.2	45	F	178.9	29820	14.5	5.0	4.0	4.68	11
*Fig. 20...	1200.366	19.4	45	F	192.0	33891	16.2	6.9	6.1	5.13	375

* No test made at this rate with Jamison coal and standard front end. The coal used in this test was similar to Jamison.

94. The test of the arrangement, Fig. 25, shows an average boiler pressure of 204.9 pounds, an evaporation of 33,722 pounds of water, or an equivalent evaporation of 16.4 pounds per square foot of heating surface. The draft in the smokebox was 6.8 inches of water, and the cinders collected were 17 pounds per hour. In the test of arrangement, Fig. 22, it will be noted that the steam pressure, the evaporation and draft in the smokebox are less, while the cinders collected are 29 pounds per hour. The

arrangement, Fig. 23, shows a still lower pressure and evaporation and 136 pounds of cinders collected per hour. The arrangement, Fig. 24, shows a still lower pressure, evaporation and draft, but it shows a very small quantity of cinders collected.

95. It will be noted, however, from Table 14, that this is an exceptionally small quantity of cinders for this front end. Table 9 brings out the fact, that while this front end shows fair results in quantity of cinders, at the same time it shows very poor results in steaming.

96. The results of the tests, showing coal fired and cinders collected in the front end, are illustrated in Fig. 26.

97. The standard front end, as would be expected, shows the largest quantity of cinders collected. The Buffalo arrangement appears to be a little better than the standard front end, which is not self-cleaning. The Sunbury front end is better than the Buffalo front. The baffle plate arrangement comes next in quantity of cinders collected, while the Lines West front, Fig. 25, shows the best results of all, with it, there is formed a small bank of cinders in front of the exhaust pipe, but as this bank does not grow to a large size the front is self-cleaning for all practical purposes.

98. The Lines West front end shows also the best evaporation. While Table 9 gives an evaporation of 33,722 pounds per hour for this front end, the locomotive was actually forced to an evaporation of 34,256 pounds per hour with this arrangement. The average boiler pressure in this latter test was, however, 191.1 pounds, indicating that the limit of boiler capacity was reached or exceeded.

99. The Buffalo and Sunbury front ends would not be difficult or expensive to apply. This does not seem to be the case, however, with the baffle plate arrangement, Fig. 22. It has all of the parts of the original standard front end, with the baffle plate added. This baffle plate has a manhole in it to be used to enter the smokebox for examination. The other front arrangements can be examined by opening the smokebox door, while with this baffle plate the inside manhole plate must be removed.

100. Having eliminated the other front ends for the reasons as given, we have remaining, the Lines West arrangement, Fig. 25. This is a simple and practical front end which gives good results in both steaming and self-cleaning.

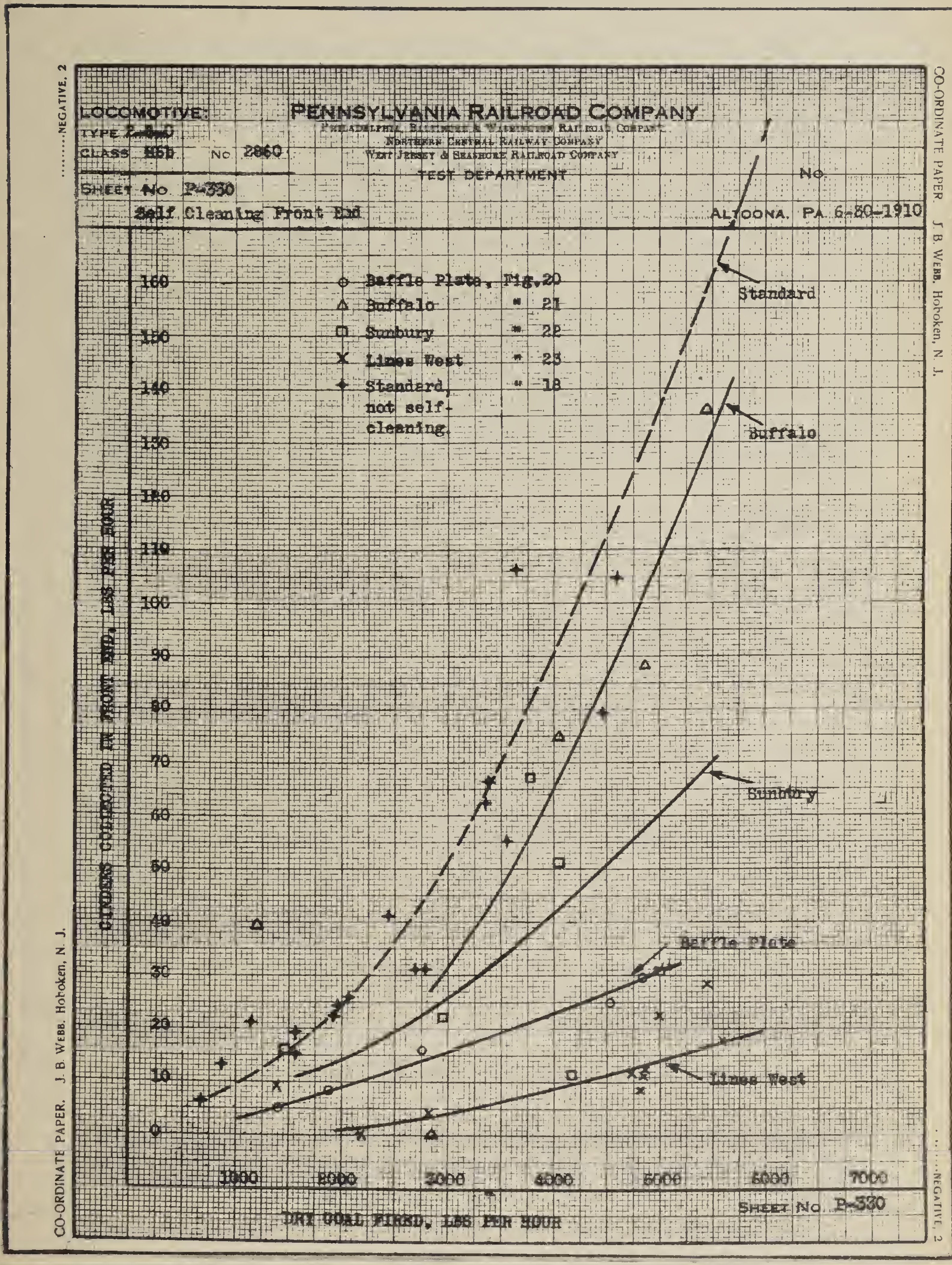


Fig. 26.

Cinders remaining in smokebox and coal fired per hour. This diagram shows how nearly the different arrangements are completely self-cleaning. The Buffalo and Sunbury fronts are little better than the standard, which is not self-cleaning.

Conclusions (E Class).

101. A front end arrangement has been developed for the E class locomotive, which while self-cleaning, maintains the boiler capacity or maximum evaporation fully equal to that with the standard front end arrangement formerly used.

102. With friable coals, where large quanties of cinders are formed, the boiler capacity will be increased on long runs, on account of the smokebox being kept clear of cinders which would obstruct the draft.

103. The outside and inside stacks as now used on this class of locomotive appear to give better results than can be obtained with the form recommended by the Master Mechanics' Committee, and it is thought advisable to retain them.

104. The diaphragm plate may be located at the proper height to produce the cleaning effect desired without causing any difficulty with the burning of the fire. (Paragraphs 29 to 31.)

105. The best results were obtained when the passage for the gases, under the diaphragm, was smooth and free from abrupt changes of form.

106. The inclined, adjustable, diaphragm plate, often used, was found to cause an obstruction to the flow of gases and is undesirable. In the experiments, the height of the whole horizontal plate of the diaphragm was varied and the final position recommended is suitable for any locomotive of this class and means for adjustment is not considered necessary.

107. The front end, Fig. 19, giving the best results is arranged as follows: The diaphragm plate has no holes in it, it extends forward 7½ inches beyond the centre of the exhaust pipe, and the forward edge is 14¾ inches above the bottom of the smokebox at the centre. The lower end of the stack is 12 inches above the exhaust nozzle. A 5¾-inch exhaust nozzle is used.

Recommendations (E Class).

108. The front end arrangement shown in Fig. 19 is the final development, and is recommended as the one giving the best results.

109. The front end arrangement is of sufficient importance in the steaming of the locomotive to have a periodic inspection for correct location of parts, and we recommend that such an inspection be made at the time of the hydrostatic test of the boiler. A blank form should be provided to be filled in with the diameter of the exhaust nozzle and the actual dimensions of the essential parts of the arrangement.

110. New locomotives, of this class, or locomotives undergoing extensive repairs should have applied the front end as shown in Fig. 19.

Conclusions (H6b Class).

111. Two of these front ends, the Buffalo and Sunbury, are scarcely to be considered as self-cleaning, and the Sunbury front with its petticoat pipe is a very poor steaming arrangement. (Paragraphs 95 and 97.)

112. The baffle plate front end gives fair results in discharging cinders and in steaming, but its extreme complication is very evident.

113. The Lines West front gave very satisfactory results in steaming and cleaning. It is a simple and practical arrangement.

Recommendations (H6b Class).

114. We recommend that in new work or in extensive repair work on smokeboxes of the H6a and H6b classes that the arrangement shown in Fig. 25 be applied, for the reason that it makes a better steaming locomotive at all times, and prevents failures, caused by the filling with cinders and burning out of the smokebox.

C. D. YOUNG,
Engineer of Tests.

Approved:
J. T. WALLIS,
Genl. Supt. Motive Power.

Test Department,
Altoona, Penna.,
August 31, 1912.

M. P. 394A
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Bulletin No. 9
TEST NOS., 900.25 to 900.47

SUBJECT: Self-cleaning Front End

ALTOONA, PA., 9-9-07

No.	Item	Value
	DRIVING WHEELS	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	ENGINE TRUCK WHEELS	
14	Number	4
15	Diameter, inches	36
	TRAILING WHEELS	
16	Diameter, inches	50
	WHEEL BASE, FEET	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels	56.13
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	37167
21	" 1st Drivers	53334
22	" 2d "	56667
23	" 3d "	——
24	" 4th "	——
25	" 5th "	——
26	" Trailers	37000
27	Total	184167
28	" on Drivers	110000
	CYLINDERS	
	Diam. and Stroke, H. P	20.5 x 26
	" " " L. P	——
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.7
41	" " Crank "	12.1
42	" Left, Head "	12.4
43	" " Crank "	11.9
44	L. P. Right, Head "	——
45	" " Crank "	——
46	" Left, Head "	——
47	" " Crank "	——
	RECEIVER, CUBIC FEET	
48	Volume Right Side	——
49	" Left "	——
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	19.87
51	" " Width	1.48
58	L. P. " Length	——
59	" " Width	——
66	H. P. Exhaust, Length	19.84
67	" " Width	2.98
70	L. P. " Length	——
71	" " Width	——

No.	Item	Value
	PISTON RODS, DIAMETER INCHES	
74	High Pressure	3.515
76	Low "	——
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	——
80	Low "	——
	VALVES	
82	Type	Double Ported Bal. Slide
83	Design	American Bal. Valve Co.
84	Per Cent. Balanced	75.7
85	Type of Valve Motion	Stephenson
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	7.0
88	Low " "	——
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	1.5
94	Low "	——
	INSIDE LAP OF VALVE	
98	High Pressure, inches	Neg. .16
102	Low " "	——
	BOILER	
113	Type	Belpaire Wide Fire box
114	Outside Diam. 1st Ring	67.0
	TUBES	
115	Number	315
116	Outside Diam., inches	20
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	——
126	Outside Diam. " inches	——
128	Length of " "	——
	FIREBOX, INSIDE, INCHES	
132	Length	114.0
133	Width	68.0
137	Air Inlets to Ashpan, sq. ft.	6.3
	GRATES	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

No.	Item	Value
	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, " "	156.86
157	" " Superh'r, " "	——
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	338.6
161	Steam " " "	109.9
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.625
167	Area, sq. inches	24.85
	REVERSE LEVER	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	——
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

*USED IN CALCULATIONS

Table 3.
Dimensions of E2a locomotive 5266.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

FUEL: Scalp Level and Penn Gas Coal

Average Results of Locomotive Tests

SUBJECT: Front End Trials

ALTOONA, PA., 9-9-1907

TEST NUMBER	RUNNING CONDITIONS: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
917	160-27-F	3.0	38.20	Full		2.1	188.4	7.7	0.3	15167	492
900.3	160-32-F	2.0	37.65	"		2.5	201.2	8.3	0.2	14360	326
900.25	160-27-F	1.5	37.65	"		1.2	179.2	4.9	0.2	15402	0
900.26	160-27-F	1.0	37.65	"		1.1	181.4	4.8	0.2	15402	0
900.28	160-25-F	2.0	37.65	"		1.2	199.0	5.0	0.2	15402	0
900.29	160-30-F	1.0	37.65	"		1.5	173.3	5.6	0.2	15402	0
900.30	160-27-F	1.0	37.65	"		1.5	186.9	5.3	0.2	15402	0
900.31	160-27-F	1.5	37.65	"		1.3	176.7	4.8	0.2	15402	0
900.32	160-27-F	1.0	37.65	"		1.4	195.1	5.2	0.2	15202	48
900.33	160-32-F	1.0	37.65	"		2.6	179.0	6.8	0.2	14229	28

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
917	4802	86.53	28670	34793	15.00	7.25	1008.5	46.17	6.2		
900.3	6039	108.81	35232	42305	18.24	7.01	1226.3	47.15	4.2		
900.25	3749	67.55	25115	29866	12.88	7.97	865.7	49.98	3.2		
900.26	4115	74.14	26296	31288	13.49	7.60	906.9	47.66	3.3		
900.28	4169	75.13	26182	31236	13.47	7.49	905.4	46.97	3.3		
900.29	4392	79.14	28245	33577	14.48	7.65	973.3	47.97	4.0		
900.30	4462	80.40	27270	32532	14.03	7.29	943.0	45.71	3.7		
900.31	3903	70.32	25797	30707	13.24	7.87	890.1	49.35	3.4		
900.32	4446	80.11	27990	33362	14.38	7.50	967.0	47.03	4.3		
900.33	5825	104.95	31613	37627	16.22	6.46	1090.7	43.85	5.9		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., Based on Fuel	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
917					Fig.2	8757	892.1	5.38	31.34		3.10	5.625
900.3					" 2	10535	1193.6	5.06	29.2		3.5	5.625
900.25					" 8	8684	872.0	4.30	28.51		3.84	5.625
900.26					" 9	8785	882.2	4.66	29.50		3.55	5.625
900.28					" 9	8926	896.3	4.65	28.89		3.55	5.750
900.29					" 10	9970	1001.2	4.39	27.92		3.76	5.750
900.30					" 10	9529	956.9	4.66	28.21		3.55	5.750
900.31					" 10	8927	896.4	4.35	28.49		3.80	5.825
900.32					" 10	10190	1023.5	4.34	27.06		3.81	5.750
900.33					" 10	10803	1084.8	5.37	28.84		3.33	5.750

Table 4.

Results of front end tests, E2a class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

FUEL: Penn Gas and Scalp Level Coal

SUBJECT: Front End Trials

ALTOONA, PA., 9-9-1907

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
900.35	160-27-F	1.0	37.65	Full		1.4	199.9	5.5	0.3	15402	10
900.36	160-27-F	1.0	37.65	"		1.4	198.6	6.3	0.3	15402	10
900.37	160-32-F	1.0	37.65	"		2.9	204.1	9.5	0.3	14233	6
900.38	160-27-F	1.0	37.65	"		1.5	200.4	5.9	0.3	15402	255
900.39	160-27-F	1.0	37.65	"		1.4	184.3	6.0	0.3	15402	76
900.40	160-27-F	0.5	37.56	"		1.2	172.5	4.5	0.2	15402	0

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
900.35	4702	84.72	28693	34243	14.76	7.28	992.6	45.65	4.5		
900.36	4285	77.21	28318	33717	14.54	7.87	977.3	49.35	4.6		
900.37	5702	102.74	35326	42141	18.17	7.39	1221.5	50.15	7.4		
900.38	4206	75.78	29201	34840	15.02	8.28	1009.9	31.92	4.7		
900.39	4478	80.68	26430	31502	13.58	7.03	913.1	44.08	3.9		
900.40									3.1		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		285	383	384	385	398	399	
900.35					Fig. 8	10418	1046.2	4.49	27.12		3.68	5.75
900.36					" 8	10324	1036.7	4.13	27.04		4.00	5.75
900.37					" 8	12198	1224.9	4.66	28.45		3.84	5.75
900.38					" 11			No record				5.75
900.39					" 11			"				5.75
900.40					" 12	8596						6.25

Table 5.
Results of front end tests, E2a class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E2a
NUMBER 5266

FUEL: Penn Gas Coal

SUBJECT: Front End Trials

ALTOONA, PA. 10-1-1907

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
900.41	160-27-F	2	37.56	Full		2.1	200.8	6.9	0.3	14382	0
900.42	160-27-F	2	37.56	"		1.9	203.4	6.7	0.3	"	0
900.43	160-27-F	2	37.56	"		2.0	204.6	7.1	0.3	"	0
900.44	160-27-F	2	37.56	"		1.9	202.3	6.8	0.3	"	0
900.45	160-32-F	2	37.56	"		2.5	199.5	8.7	0.4	"	0
900.46	160-27-F	2	37.56	Partial		0.6	203.8	1.8	0.2	"	3
900.47	160-27-F	2	37.56	Full		1.9	195.8	5.7	0.3	"	10

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Equivalent Evaporation: Per Hour per Sq. Ft. of Fire Heating Sur.	Equivalent Evaporation: Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
900.41	4489	80.88	31165	37282	16.07	8.31	1080.7	55.80	5.5		
900.42	3888	70.05	29705	35552	15.33	9.14	1030.5	61.38	5.2		
900.43	4641	83.62	31032	37177	16.03	8.01	1077.6	53.79	5.6		
900.44	3776	68.04	30437	36458	15.72	9.66	1056.8	64.87	5.4		
900.45	4799	86.47	34676	41497	17.89	8.65	1202.8	58.09	6.7		
900.46	1421	25.60	14206	16970	7.32	11.94	491.9	80.18	1.5		
900.47	4030	72.61	28882	34525	14.89	8.57	1000.7	57.55	4.6		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent. (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	389	
900.41					Fig. 14	10822	1084.1	4.14	28.46		4.27	5.75
900.42					" 15	10334	1035.3	3.76	28.39		4.71	5.75
900.43					" 15	10250	1026.8	4.52	29.66		3.91	5.75
900.44					" 16	10400	1041.9	3.62	28.91		4.89	5.75
900.45					" 16	11967	1198.9	4.00	28.63		4.42	5.75
900.46					" 16	3994	400.1	3.55	34.63		4.98	5.75
900.47					" 16	10142	1016.0	3.97	28.13		4.46	5.75

Table 6.
Results of front end tests, E2a class locomotive.

M. P. 894A
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Bulletin No. 9
TEST NOS.,
1001 to 1008 incl.

SUBJECT: Self-cleaning Front End

ALTOONA, PA., 11-4-07

No.	Item	Value
	Driving Wheels	
1	Number of Pairs	2
2	Approx. Diameter, inches	80
	Engine Truck Wheels	
14	Number	4
15	Diameter, inches	36
	Trailing Wheels	
16	Diameter, inches	50
	Wheel Base, Feet	
17	Driving Wheel Base	7.42
18	Total Wheel Base	30.85
19	Gage of Wheels	4.71
	Weight of Engine with Water at 2d. Gage Cock and Normal Fire, Pounds	
20	On Truck	33700
21	" 1st Drivers	56700
22	" 2d "	61500
23	" 3d "	---
24	" 4th "	---
25	" 5th "	---
26	" Trailers	31200
27	Total	183100
28	" on Drivers	118200
	Cylinders	
	Diam. and Stroke, H. P	22 x 26
	" " " L. P.	---
	Clearance in per cent. of Piston Displacement	
40	H. P. Right, Head End	+
41	" " Crank "	+
42	" Left, Head "	+
43	" " Crank "	+
44	L. P. Right, Head "	---
45	" " Crank "	---
46	" Left, Head "	---
47	" " Crank "	---
	Receiver, Cubic Feet	
48	Volume Right Side	---
49	" Left "	---
	Steam Ports, Inches	
50	H. P. Admission, Length	20
51	" " Width	1.5
58	L. P. " Length	---
59	" " Width	---
66	H. P. Exhaust, Length	20
67	" " Width	3
70	L. P. " Length	---
71	" " Width	---

No.	Item	Value
	Piston Rods, Diameter Inches	
74	High Pressure	4
76	Low "	---
	Tail Rods, Diameter, Inches	
78	High Pressure	---
80	Low "	---
	Valves	
82	Type	Richardson Balanced
83	Design	
84	Per Cent. Balanced	
85	Type of Valve Motion	Stephenson
	Greatest Valve Travel	
86	High Pressure, inches	+
88	Low " "	---
	Outside Lap of Valve	
90	High Pressure, inches	+
94	Low " "	---
	Inside Lap of Valve	
98	High Pressure, inches	+
102	Low " "	---
	Boiler	
113	Type	Belpaire Wide Fire Box
114	Outside Diam. 1st Ring	67
	Tubes	
115	Number	315
116	Outside Diam., inches	2
	Pitch "	2.625
118	Length Between Tube Sheets, inches	179.78
119	Total Fire Area, sq. ft.	5.26
124	Boiler Pressure, pounds	205
	Superheater	
125	Number of Tubes	---
126	Outside Diam. " inches	---
128	Length of " "	---
	Firebox, Inside, Inches	
132	Length	114
133	Width	68
137	Air Inlets to Ashpan, sq. ft.	6.3
	Grates	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	55.5
146	Area of Dead Grates	6.0

No.	Item	Value
	Heating Surface, Square Feet	
154	Of the Tubes, Water Side	2471.04
155	" " " Fire "	2162.40
156	" " Firebox, " "	156.86
157	" " Superh'r, " "	---
*158	Total, Based on " "	2319.26
159	" " " " " of Firebox and Water Side of Tubes	2627.90
	Boiler Volume with Water Surface at Level of 2d Gage Cock	
160	Water Space, cu. ft.	+
161	Steam " " "	+
	Exhaust Nozzle	
162	Double or Single	Single
163	Size, inches	5.75
167	Area, sq. inches	25.97
	Reverse Lever	
168	H. P. Notches Forward of Center	15
169	L. P. Notches Forward of Center	---
	Ratios	
171	Heating Surface (158) to Grate Area (145)	41.79
172	Fire Area Thru Tubes (119) to Grate Area (145)	.09
173	Firebox Heating Surface (156) to Grate Area (145)	2.83
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	13.79

+ These items not measured

*USED IN CALCULATIONS

Table 7.
Dimensions of E3a class locomotive 2984.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3a
NUMBER 2984

FUEL: Penn Gas Coal

SUBJECT: Front End Tests

ALTOONA, PA., 11-4-1907

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	236
1001	200-25-F	1.00	46.27	Full		2.3	199.6	8.6	0.3	14088	0
1002	160-30-F	1.00	37.02	"		2.2	201.9	8.7	0.3	14088	0
1003	160-30-F	0.83	37.02	"		1.8	200.5	7.2	0.3	14088	0
1004	160-25-F	2.00	37.02	"		1.9	199.9	6.7	0.4	14088	0
1005	120-20-F	2.00	27.76	"		1.2	202.7	3.6	0.2	14088	0
1006	160-30-F	1.00	37.02	"		2.2	200.4	7.2	0.4	14088	0
1007	160-23-F	1.00	37.02	"		1.8	200.4	5.6	0.3	11917	0
1008	200-25-F	1.00	46.27	"		2.2	202.7	7.1	0.4	14616	0

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. in.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1001	5523	99.51	34088	41111	17.75	7.44	1191.7	51.00	6.1		
1002	4321	77.86	33330	40142	17.31	9.29	1163.6	63.59	5.9		
1003	4577	82.47	32211	38370	16.76	8.49	1126.7	58.20	5.3		
1004	3803	68.52	30000	36255	15.63	9.56	1050.9	65.33	4.9		
1005	2503	45.10	20823	25183	10.86	10.06	730.0	68.97	2.7		
1006	4501	81.10	32375	39237	16.92	8.72	1137.3	59.78	5.2		
1007	4409	79.44	25970	31297	13.49	7.10	907.2	57.54	4.3		
1008	5016	90.38	33695	40891	17.63	8.15	1185.3	53.85	5.6		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1001					Fig.16	10397	1283.0	4.30	26.26		4.20	5.75
1002					" 16	12914	1274.9	3.39	25.87		5.33	5.75
1003					" 17	12717	1255.4	3.65	25.40		4.95	5.75
1004					" 17	11876	1172.4	3.24	25.32		5.58	5.75
1005					" 18	10957	811.3	3.09	25.40		5.85	5.75
1006					" 18	12765	1260.2	3.57	25.34		5.06	5.75
1007					" 19	10605	1046.6	4.21	24.49		5.07	5.75
1008					" 19	10109	1247.5	4.02	26.66		4.33	5.75

Table 8.
Results of front end tests, E3a class locomotive.

M. P. 894A
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8b
NUMBER 2860

Bulletin No.9
TEST NOS.,

SUBJECT: Self Cleaning Front End

ALTOONA, PA. 8-10-1908

	Driving Wheels	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	Engine Truck Wheels	
14	Number	2
15	Diameter, inches	30
	Trailing Wheels	
16	Diameter, inches	—
	Wheel Base, Feet	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	Weight of Engine with Water at 2d. Gage Cock and Normal Fire, Pounds	
20	On Truck	21667
21	" 1st Drivers	45667
22	" 2d "	42583
23	" 3d "	47500
24	" 4th "	40850
25	" 5th "	—
26	" Trailers	—
27	Total	198267
28	" on Drivers	176600
	Cylinders	
	Diam. and Stroke, H. P	22 x28
	" " " L. P	—
	Clearance in per cent. of piston displacement	
40	H. P. Right, Head End	12.5
41	" " Crank "	10.7
42	" Left, Head "	12.2
43	" " Crank "	10.8
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	Receiver, Cubic Feet	
48	Volume Right Side	—
49	" Left "	—
	Steam Ports, Inches	
50	H. P. Admission, Length	30
51	" " Width	2
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	No Port
67	" " Width	" "
70	L. P. " Length	—
71	" " Width	—

	Piston Rods, Diameter Inches	
74	High Pressure	4
76	Low "	—
	Tail Rods, Diameter, Inches	
78	High Pressure	None
80	Low "	—
	Valves	
82	Type	Piston
83	Design	Amer.Bal.Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walschaerts
	Greatest Valve Travel	
86	High Pressure, inches	6.25
88	Low " "	—
	Outside Lap of Valve	
90	High Pressure, inches	.91
94	Low " "	—
	Inside Lap of Valve	
98	High Pressure, inches	.06
102	Low " "	
	Boiler	
113	Type	Belpaire,Wide Firebox
114	Outside Diam. 1st Ring	71.16
	Tubes	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.6875
118	Length Between Tube Sheets, inches	164.28
119	Total Fire Area, sq. ft.	6.23
124	Boiler Pressure, pounds	205
	Superheater	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	Firebox, Inside, Inches	
132	Length	118.32
133	Width	65.04
137	Air Inlets to Ashpan, sq. ft.	7.56
	Grates	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	48.66
146	Area of Dead Grates	0

	Heating Surface, Square Feet	
154	Of the Tubes, Water Side	2673.68
155	" " " Fire "	2339.23
156	" " Firebox, " "	166.06
157	" " Superh'r, " "	—
*158	Total, Based on " "	2505.29
159	" " " " " of Firebox and Water Side of Tubes	2839.74
	Boiler Volume with water surface at level of 2d gage cock	
160	Water Space, cu ft	349.7
161	Steam " " "	65.1
	Exhaust Nozzle	
162	Double or Single	Single
163	Size, inches	5.63
167	Area, sq. inches	24.89
	Reverse Lever	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	—
	Ratios	
171	Heating Surface (158) to Grate Area (145)	51.49
172	Fire Area Thru Tubes (119) to Grate Area (145)	.13
173	Firebox Heating Surface (156) to Grate Area (145)	3.41
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.09

*USED IN CALCULATIONS

Table 9.
Dimensions of H6b class locomotive 2860.

M. P. 394 A—Sixth Sheet
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	203 to 271		217	222	225	248	238
1200.276	80-20-F	2.25	13.00	Full	19.2	0.7	204.6	1.3	0.1	13176	21
1200.271	80-30-F	3.00	13.00	"	31.4	1.1	204.6	2.6	0.1	13176	26
1200.272	80-40-F	2.50	13.00	"	38.9	1.6	204.8	3.4	0.1	13176	31
1200.275	120.40-F	2.00	19.50	"	38.9	1.9	204.5	5.2	0.2	14137	79
1200.286	140-40-F	.75	22.75	"	13.9	2.1	200.5	5.8	0.1	14137	436

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.276	1734	35.64	13890	16669	6.65	9.61	483.2	70.44	1.1		
1200.271	2593	53.29	19628	23750	9.48	9.16	688.4	67.14	2.3		
1200.272	3289	67.59	24036	29104	11.62	8.85	843.6	64.87	3.0		
1200.275	4950	101.73	31111	37632	15.02	7.60	1090.7	51.92	4.6		
1200.286	6336	130.21	33188	39989	15.96	6.31	1159.1	43.11	5.2		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.276	13061	520.2	3.3	25.11	Fig.20	12014	428.5	4.1	30.48	82.4	4.75	5.5
1200.271	19387	817.6	3.2	23.71	"	20234	701.4	3.7	27.64	85.8	5.22	"
1200.272	23723	963.5	3.4	24.62	"	24526	850.2	3.9	27.90	88.2	4.99	"
1200.275	30723	1252.8	4.0	24.52	"	20998	1091.8	4.5	28.14	87.1	3.97	"
1200.286	32786	1308.4	4.8	25.06	"	18771	1138.7	5.6	28.79	87.0	3.24	"

Table 10.

Results of tests of standard front end, H6b class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft In Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.423	80-20-F	2.0	12.86	Full		0.6	204.6	1.4	0.0	12928	5
1200.422	80-30-F	2.0	12.86	"		0.8	203.7	2.1	0.2	"	8
1200.424	80-40-F	2.0	12.86	"		1.2	204.3	3.3	0.1	"	16
1200.425	120.40-F	2.0	19.30	"		2.1	201.4	5.2	0.2	"	25
1200.428	120-40-F	1.5	19.30	"		1.5	202.0	5.6	0.2	13390	0
1200.426	120-45-F	1.0	19.30	"		2.3	159.9	5.6	0.2	12928	29
1200.427	120-45-F	1.0	19.30	"		2.4	201.6	5.7	0.1	13390	29

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.423	1921	39.48	14658	17781	7.10	9.26	515.4	69.18	1.2		
1200.422	2381	48.93	17766	21530	8.59	9.04	624.1	67.54	1.9		
1200.424	3264	67.08	23315	28390	11.33	8.70	822.9	65.00	3.0		
1200.425	5017	103.11	30430	37175	14.84	7.41	1077.5	55.36	4.6		
1200.428	5133	105.48	31296	38192	15.25	7.44	1107.0	53.66	4.8		
1200.426	5323	109.40	31253	38119	15.21	7.16	1104.7	53.49	4.8		
1200.427	5301	108.93	32438	39625	15.82	7.48	1148.5	53.95	5.1		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.423	14275				Fig.22	14282	489.9	3.92	29.14		5.02	5.50
1200.422	17501				"	18695	641.3	3.71	27.29		5.31	"
1200.424	22937				"	24580	843.2	3.87	27.20		5.09	"
1200.425	30062				"	20316	1047.7	4.79	28.69		4.11	"
1200.428	30897				"	20600	1060.0	4.84	29.15		3.93	"
1200.426	30875				"	20472	1053.4	5.05	29.31		3.90	"
1200.427	32046				"	21164	1089.0	4.87	29.43		3.90	"

Table 11.
Results of tests of baffle plate front end, H6b class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft In Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.436	80-20-F	1.0	12.86	Full		0.4	151.9	0.9	No Record	13390	39
1200.435	80-40-F	2.0	12.86	"		1.2	204.0	3.0	0.1	13390	0
1200.437	120.40-F	1.5	19.30	"		1.6	179.4	4.1	0.2	12444	75
1200.447	120-40-F	1.5	19.23	"		2.1	200.4	4.7	0.1	14315	88
1200.448	120-45-F	1.0	19.23	"		2.4	188.3	5.1	0.2	14315	136

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Equivalent Evaporation: Per Hour per Sq. Ft. of Fire Heating Sur.	Equivalent Evaporation: Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.436	1712	35.18	13312	16147	6.45	9.43	468.0	68.02	0.8		
1200.435	3346	68.77	23467	28492	11.37	8.52	825.9	61.45	2.8		
1200.437	4547	93.44	28258	34356	13.71	7.56	995.8	58.67	3.6		
1200.447	5363	110.21	30642	37242	14.87	6.95	1079.5	46.89	4.4		
1200.448	5947	122.20	31208	38004	15.17	6.39	1101.5	43.11	4.9		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.*	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.436	13151				Fig.23	9907	339.8	5.04	38.71		3.77	5.625
1200.435	23104				"	24819	851.4	3.93	27.14		4.84	"
1200.437	27916				"	18226	937.9	4.85	29.76		4.22	"
1200.447	30252				"	21015	1077.6	4.98	28.07		3.57	"
1200.448	30830				"	20862	1069.7	5.56	28.82		3.20	"

Table 12.
Results of tests of Buffalo front end, H6b class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½ 11-9-10

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

SUBJECT: Self Cleaning Front End. ALTOONA, PA., 6-29-1910

Test Number	Running Conditions: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft In Firebox	Boiler Performance: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.441	80-20-F	2	12.82	Full		0.6	204.9	1.5	No	12444	16
1200.438	80-40-F	2	12.82	"		1.8	203.5	3.3	Record	"	22
1200.439	120-40-F	2	19.23	"		1.9	182.4	4.6	"	"	51
1200.442	120-40-F	1	19.23	"		1.3	165.4	3.5	"	"	67
1200.440	120-45-F	1	19.23	"		1.9	178.9	5.0	.1	"	11

Test Number	Boiler Performance: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	Engine Performance: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.441	1982	40.73	14786	17927	7.16	9.05	519.6	70.23	1.3		
1200.438	3468	71.27	23681	28758	11.48	8.29	833.6	64.34	3.7		
1200.439	4564	93.79	28291	34419	13.74	7.54	997.6	58.52	4.0		
1200.442	4272	87.80	25508	30957	12.36	7.25	897.3	56.26	2.8		
1200.440	4657	95.71	29820	36302	14.49	7.80	1052.3	60.54	4.0		

Test Number	Engine Performance: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	Locomotive Performance: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.441	14561				Fig. 24	14920	510.1	3.89	28.55		5.26	5.625
1200.438	23359				"	24908	851.6	4.07	27.43		5.02	5.625
1200.439	27949				"	18663	957.0	4.77	29.20		4.29	5.625
1200.442	25199				"	16330	852.7	5.01	29.55		4.08	5.50
1200.440	29459				"	19396	994.5	4.68	29.62		4.37	5.625

Table 13.

Results of tests of Sunbury front end, H6b class locomotive.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Jamison Coal

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Self Cleaning Front End

ALTOONA, PA., 6-29-1910

TEST NUMBER	RUNNING CONDITIONS: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Draft in Firebox	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.432	80-20-F	2.0	12.86	Full		0.6	203.3	1.7	0.1	13390	9
1200.452	80-30-F	2.0	12.78	"		1.2	204.9	3.6	0.1	13888	0
1200.429	80-40-F	2.0	12.86	"		1.1	204.5	4.0	0.1	13390	4
1200.451	100-45-F	1.5	15.98	"		2.0	203.5	7.3	0.1	13888	11
1200.430	120-40-F	1.5	19.30	"		1.8	195.8	6.3	0.2	13390	8
1200.431	120-45-F	1.0	19.30	"		2.1	203.7	6.9	0.2	13390	12
1200.444	120-45-F	1.0	19.23	"		1.7	190.6	6.1	No	14315	22
1200.445	120-45-F	1.0	19.23	"		2.3	194.6	6.8	Record	14315	23
1200.446	120-45-F	1.0	19.23	"		1.9	204.9	6.8	0.1	14315	17
1200.434	120-50-F	1.0	19.30	"		2.3	191.1	7.4	0.2	13390	11

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Draft Back of Diaph.	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.432	1923	39.52	14723	17906	7.15	9.31	519.0	67.15	1.1		
1200.452	2700	55.49	21731	26157	10.44	9.69	758.2	67.39	2.6		
1200.429	3333	68.47	23995	29250	11.68	8.78	847.8	63.33	2.6		
1200.451	5222	107.32	33315	40074	16.00	7.67	1161.6	53.34	5.1		
1200.430	5290	108.71	30521	37265	14.87	7.04	1080.1	50.78	4.4		
1200.431	5342	109.78	33098	40376	16.12	7.56	1170.3	54.53	4.7		
1200.444	5473	112.47	31622	38511	15.37	7.04	1116.3	47.50	4.3		
1200.445	5947	122.20	32200	39187	15.64	6.59	1135.8	44.46	5.1		
1200.446	6097	125.29	33722	41006	16.37	6.73	1188.5	45.40	4.9		
1200.434	5345	109.84	34256	41734	16.66	7.81	1209.6	56.33	5.2		

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Front End	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	Exhaust Nozzle Diameter
	214	379	380	381		265	383	384	385	398	399	
1200.432	14515				Fig.25	14830	508.8	3.78	28.53		5.05	5.625
1200.452	20972				"	22538	768.3	3.51	27.30		5.22	"
1200.429	23502				"	24889	853.9	3.90	27.52		4.87	"
1200.451	32889				"	26967	1149.1	4.54	28.62		4.04	"
1200.430	30152				"	20156	1037.1	5.10	29.07		3.73	"
1200.431	32698				"	21398	1101.4	4.85	29.70		3.92	"
1200.444	31239				"	20809	1067.0	5.13	29.28		3.47	"
1200.445	31810				"	21427	1098.7	5.41	28.95		3.29	"
1200.446	33207				"	22163	1136.4	5.37	29.22		3.31	"
1200.434	33842				"	21748	1119.1	4.78	30.24		3.98	"

Table 14.

Results of tests of Lines West front end, H6b class locomotive.

GRAPHICAL LOGS OF TESTS.

A graphical log is made for each test to show the conditions at each ten-minute interval, and to indicate any irregularity in the weights of coal and water during the run. These diagrams are on file with the Test Plant records. A few representative ones only being shown here.

M. P. Experimental D-1

12 9 1911
8 x 10½

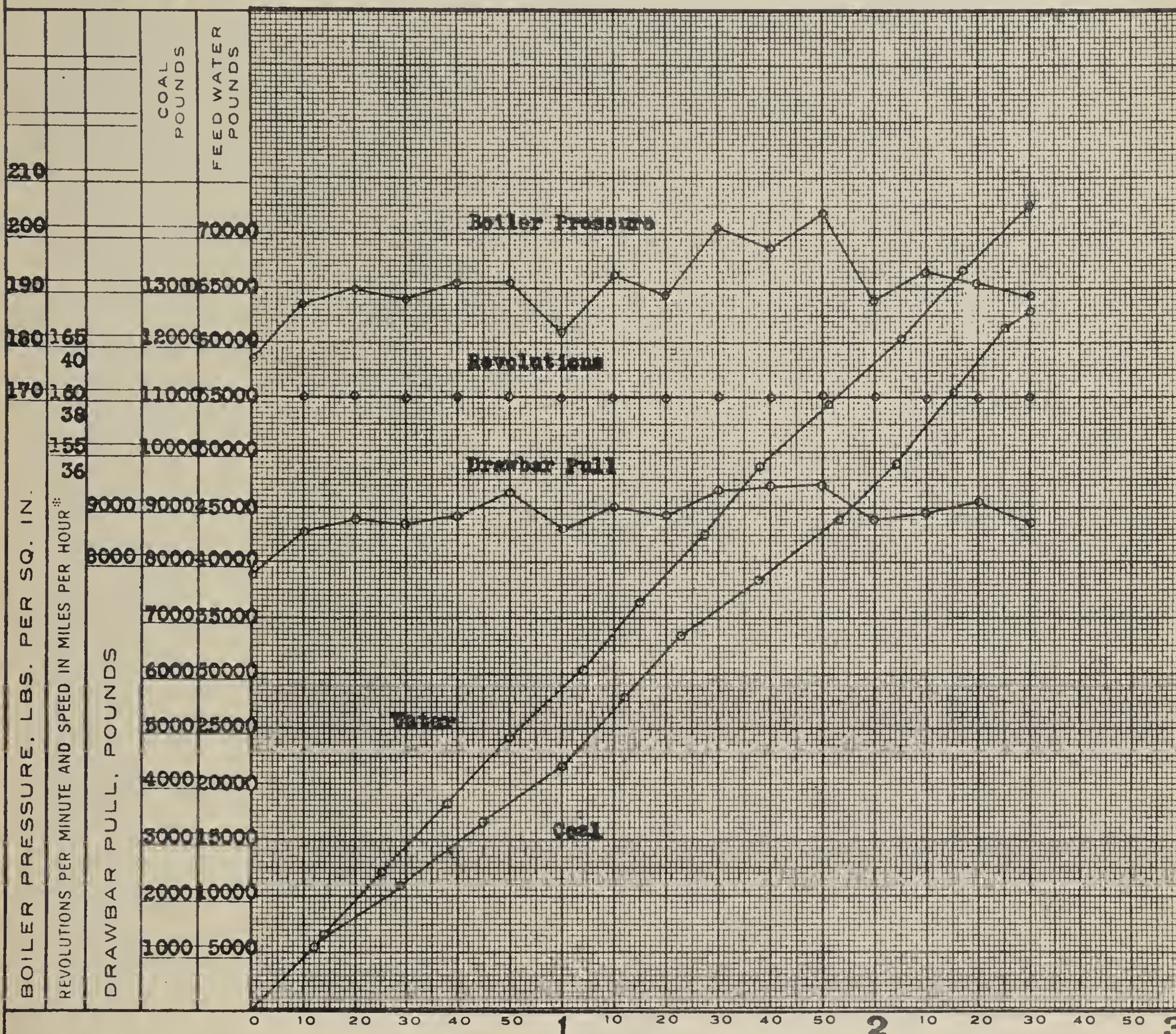
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-331 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 11-28-1912



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
36.2	160	27	F	5.91

TEST NO. 917

SHEET NO. P-331

M. P. Experimental D-1

12 9 1911
8 x 10½

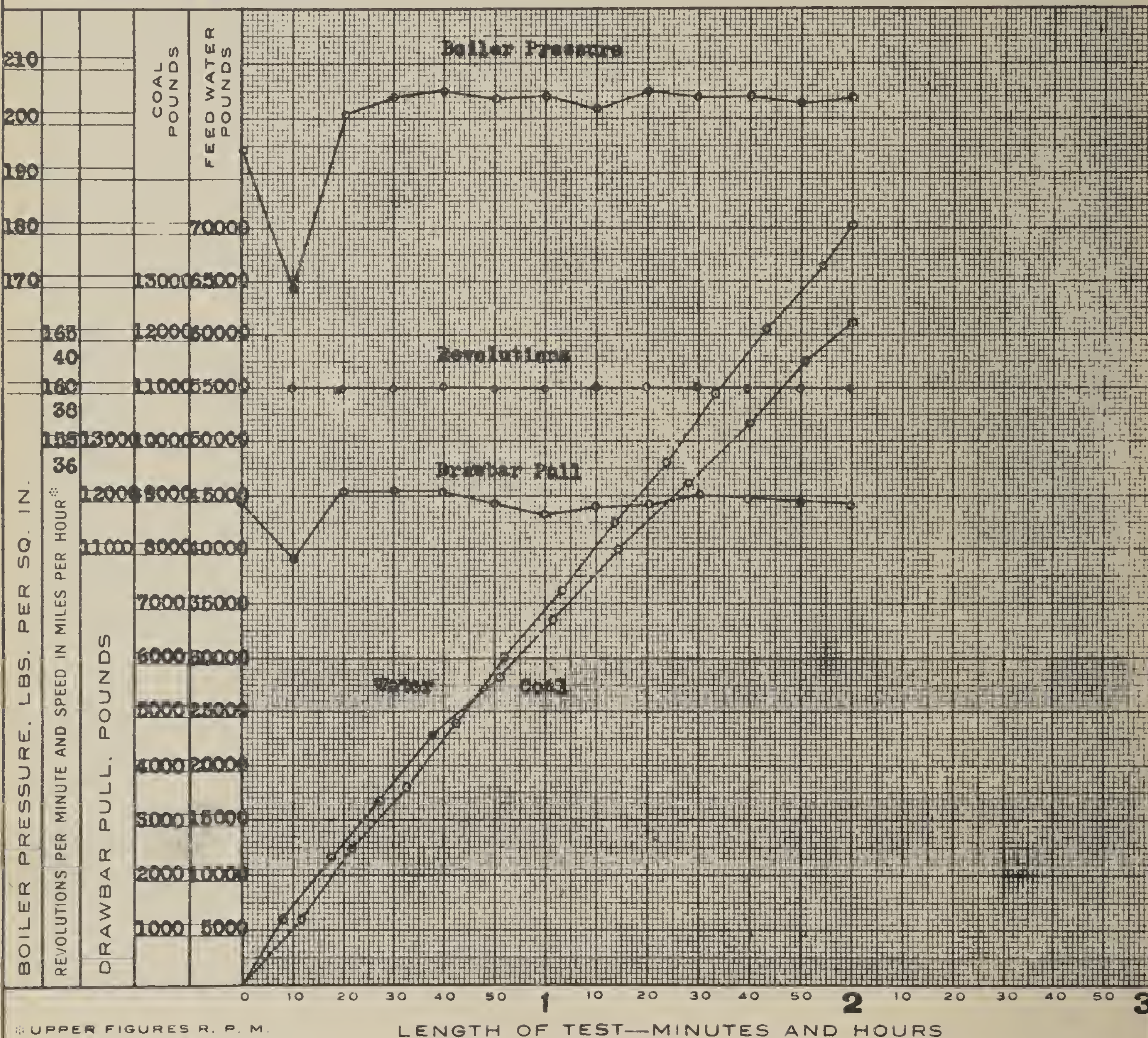
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-332 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 7-3-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
38.2	160	32	P	5.76

TEST NO. 900.3

SHEET NO. P-332

M. P. Experimental D-1

12 9 1911
8 x 10½

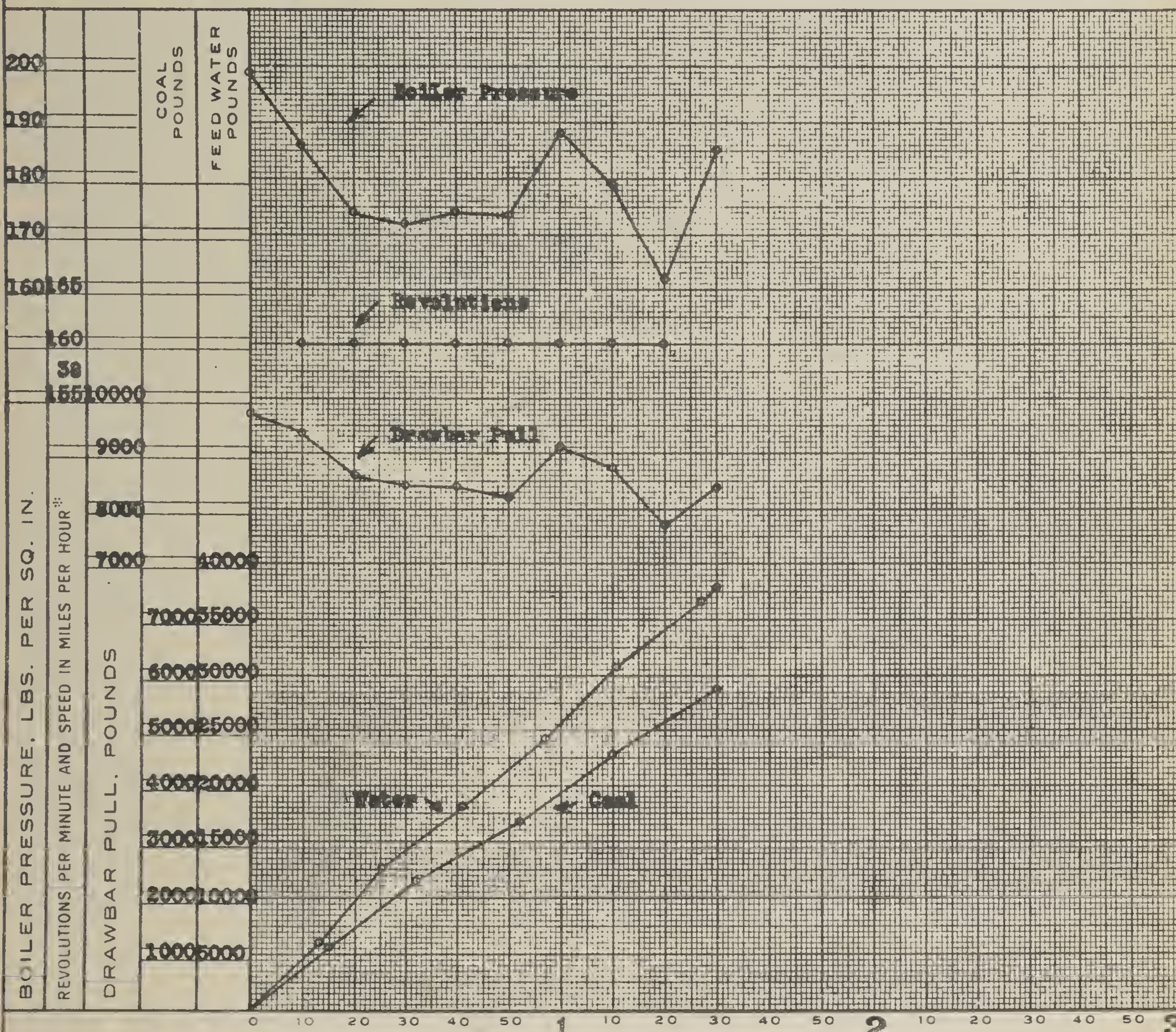
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-333 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 8-6-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.6

TEST NO. 900.25

SHEET NO. P-333

M. P. Experimental D-1

12 9 1911
8 x 10½

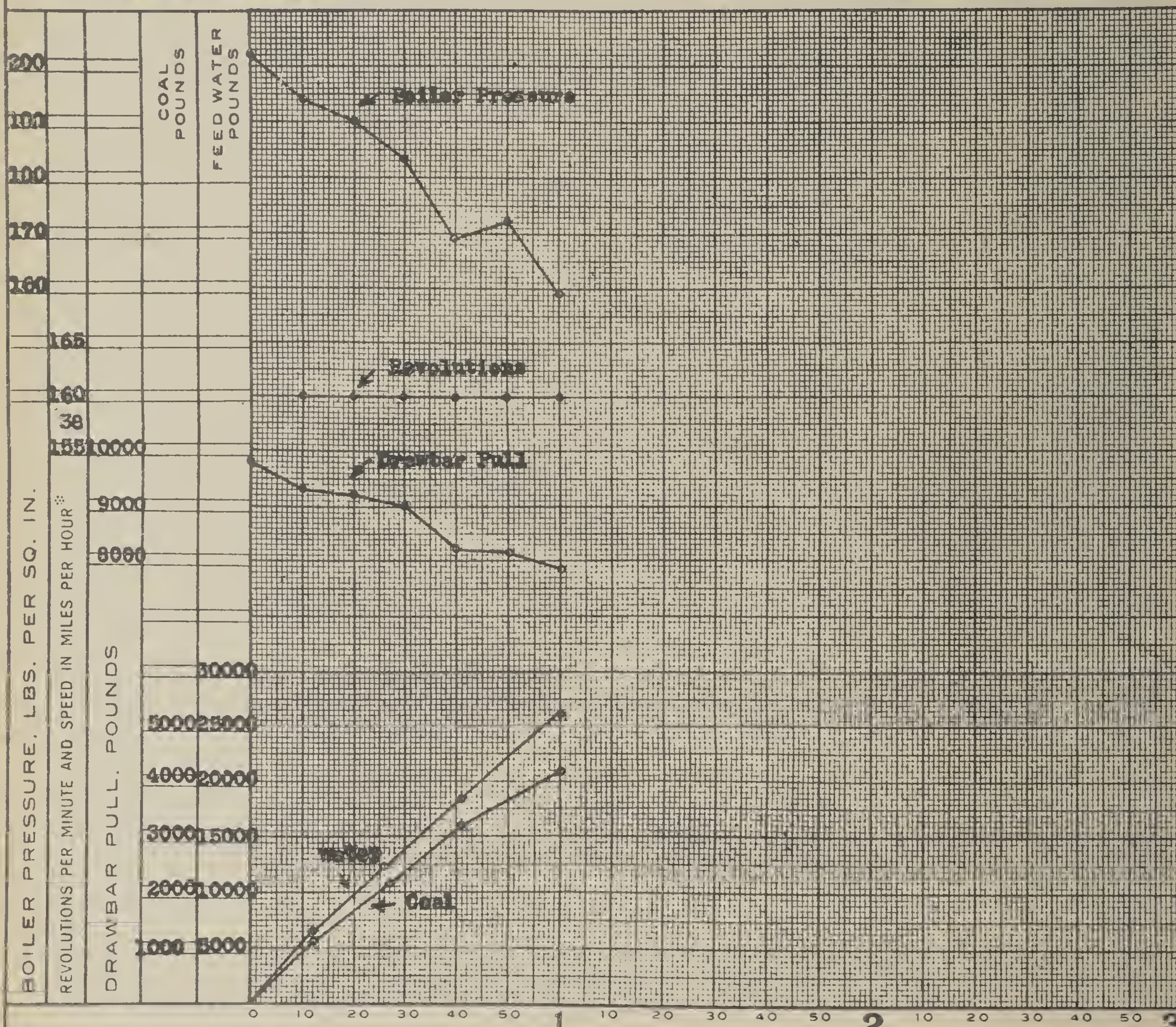
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-334 | TEST DEPARTMENT | Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End | ALTOONA, PA., 8-7-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent. H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.3

TEST NO. 900.26

SHEET NO. P-334

M. P. Experimental D-1

12 2 1941
8 x 10½

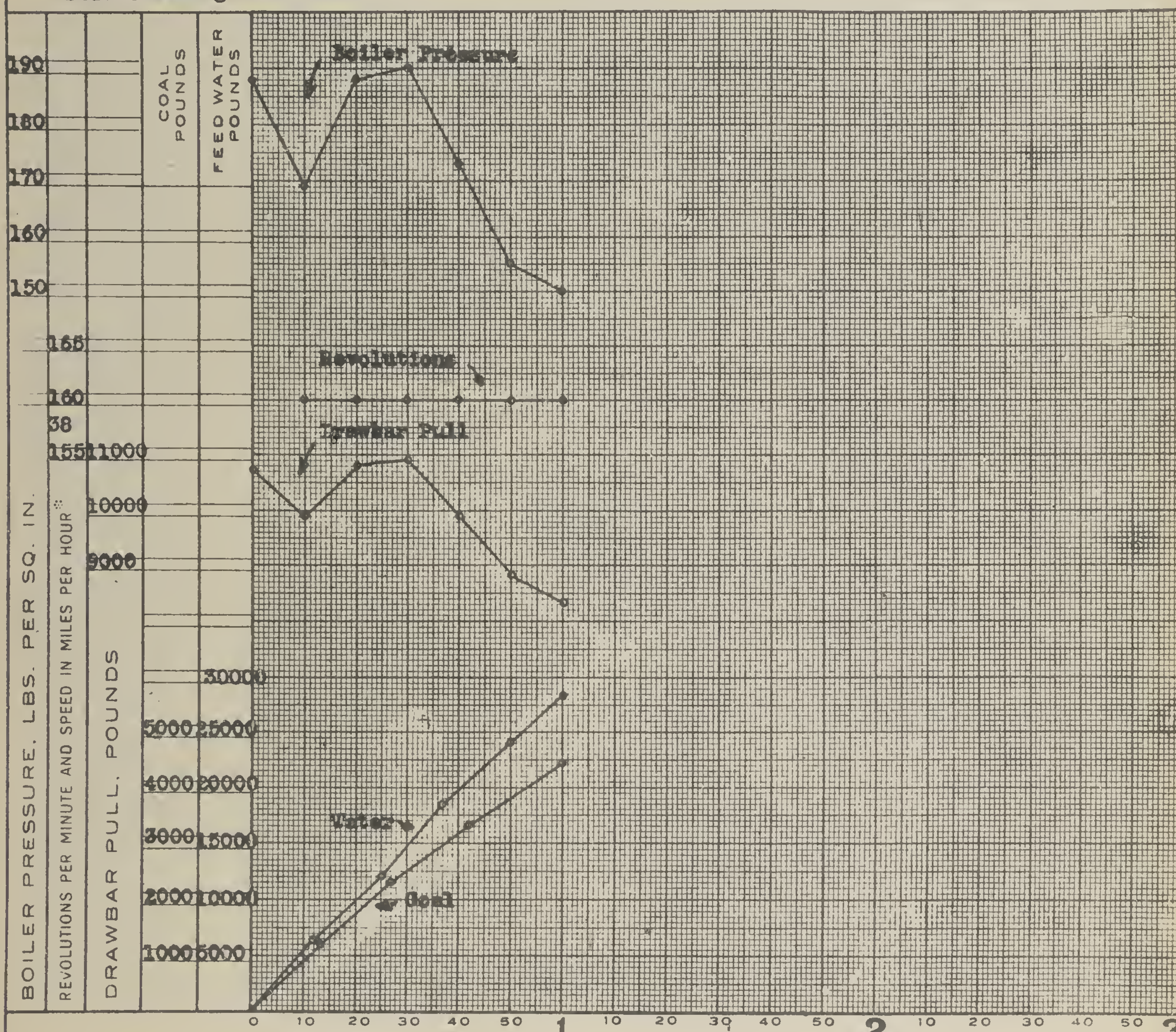
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-335 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 8-12-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	30	Full	6.4

TEST NO. 900.29

SHEET NO. P-335

M. P. Experimental D-1

12 8 1911
8 x 10½

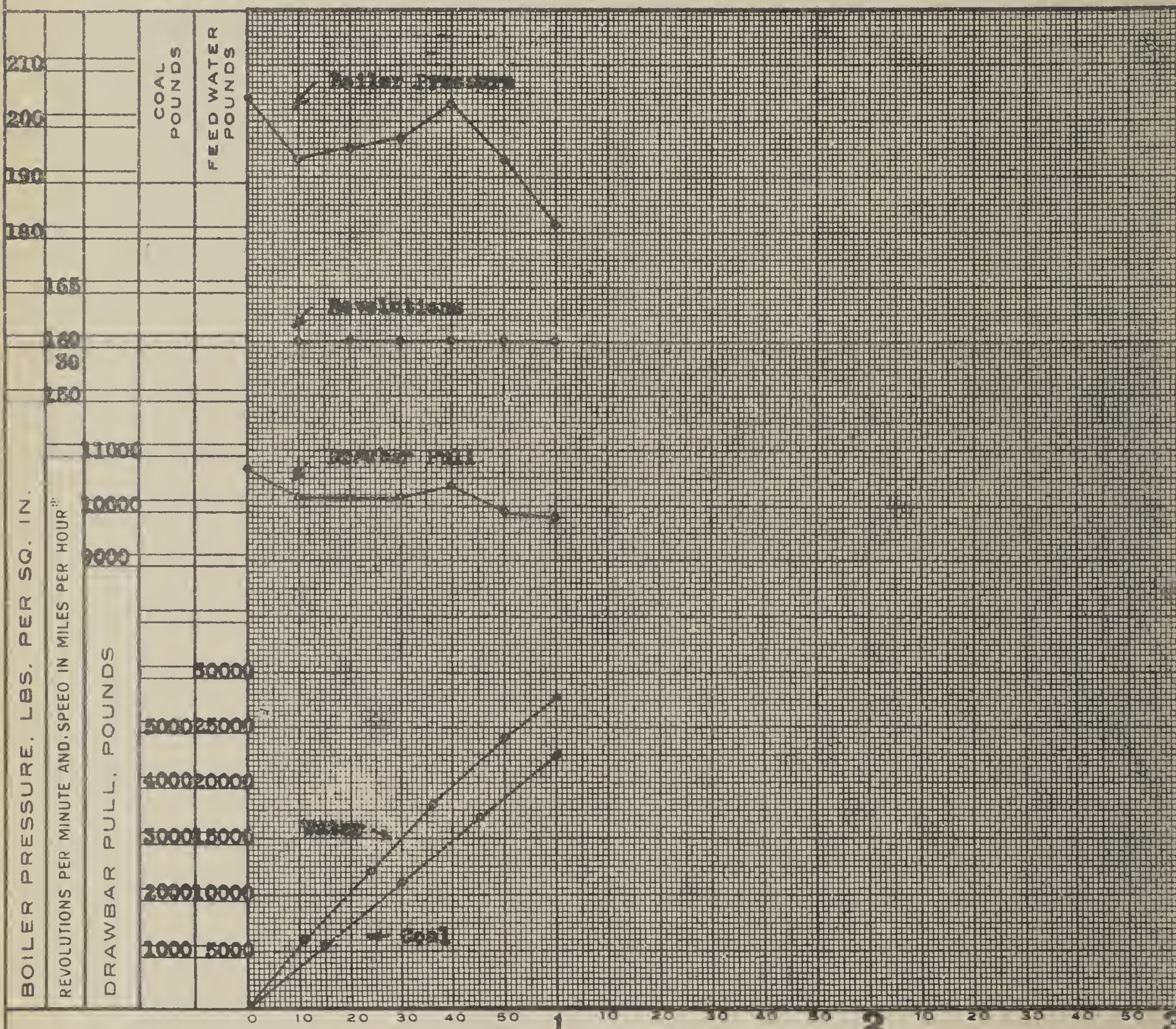
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-336 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 8-14-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	37	Full	6.2

TEST NO. 900.32

SHEET NO. P-336

M. P. Experimental D-1 | 12 9 1911 / 8 x 10½

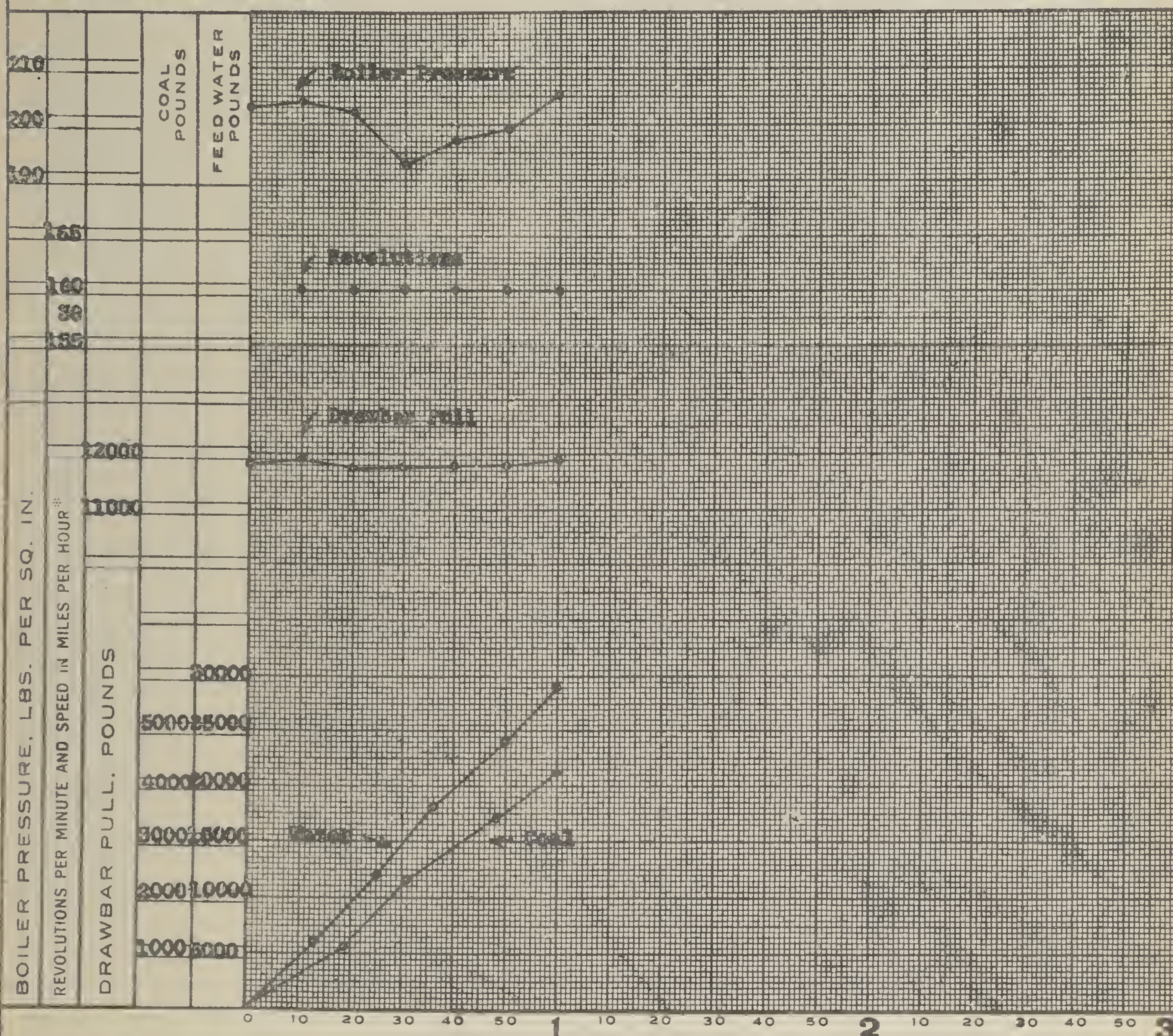
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-337 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 8-23-1907



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.9

TEST NO. 900.38

SHEET NO. P-337

M. P. Experimental D-1

12 8 1911
8 x 10½

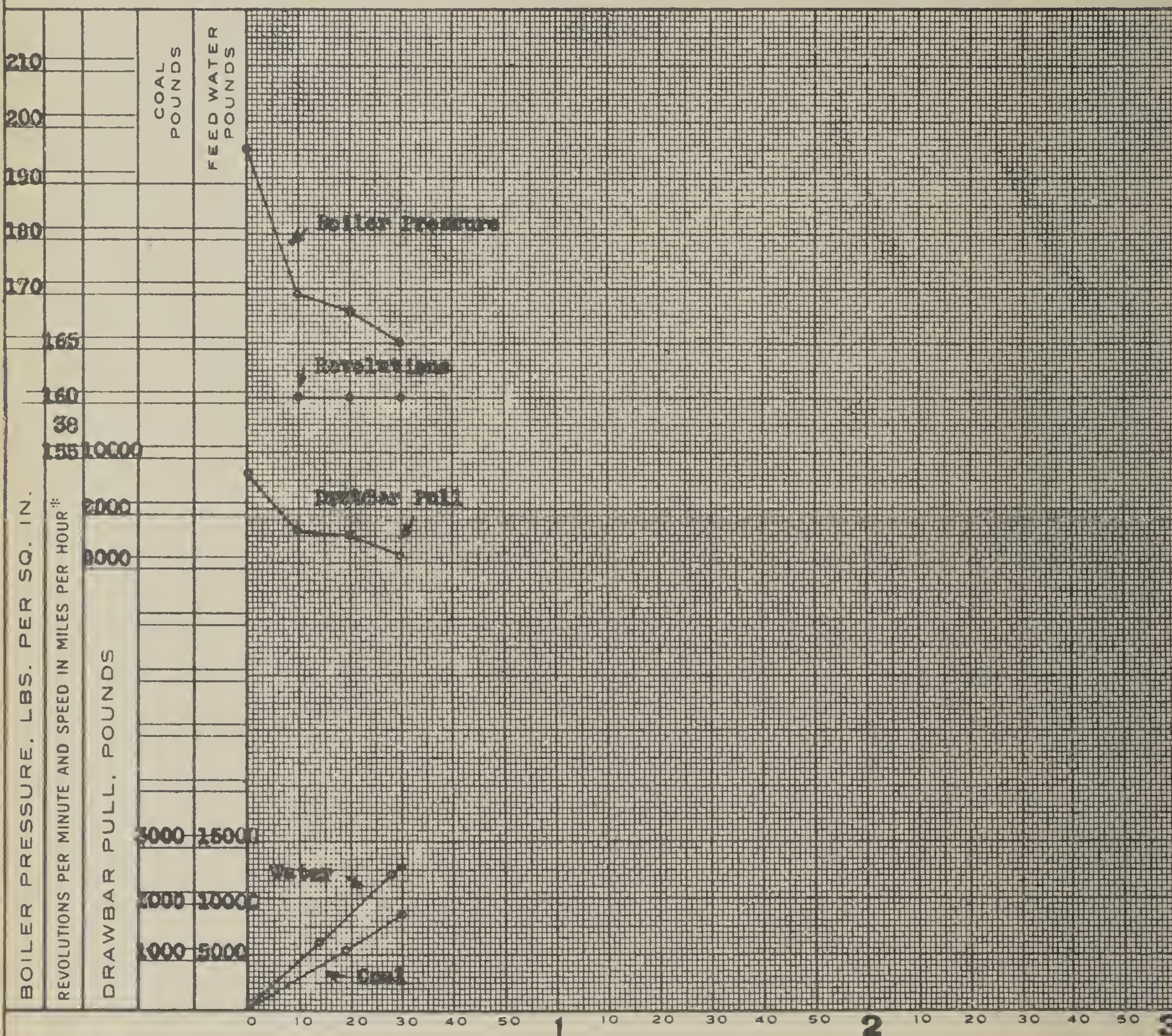
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-338 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 9-3-1907



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.8

TEST NO. 900,40

SHEET NO. P-338

M. P. Experimental D-1

12 9 1911
8 x 10½

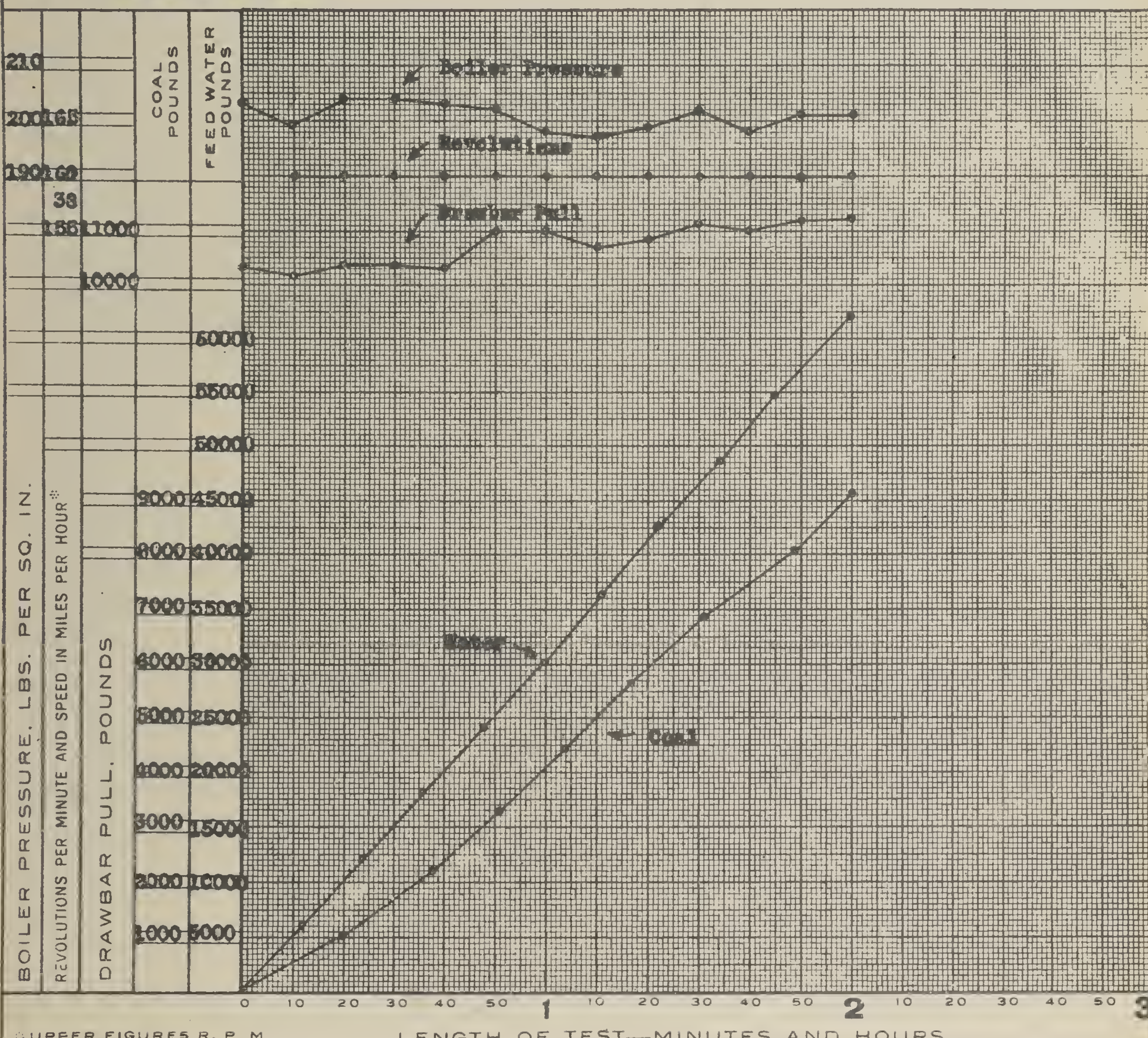
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-339 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 9-11-1907



*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	6.8

TEST NO. 900.41

SHEET NO. P-339

M. P. Experimental D-1

12 9 1911
8 x 10½

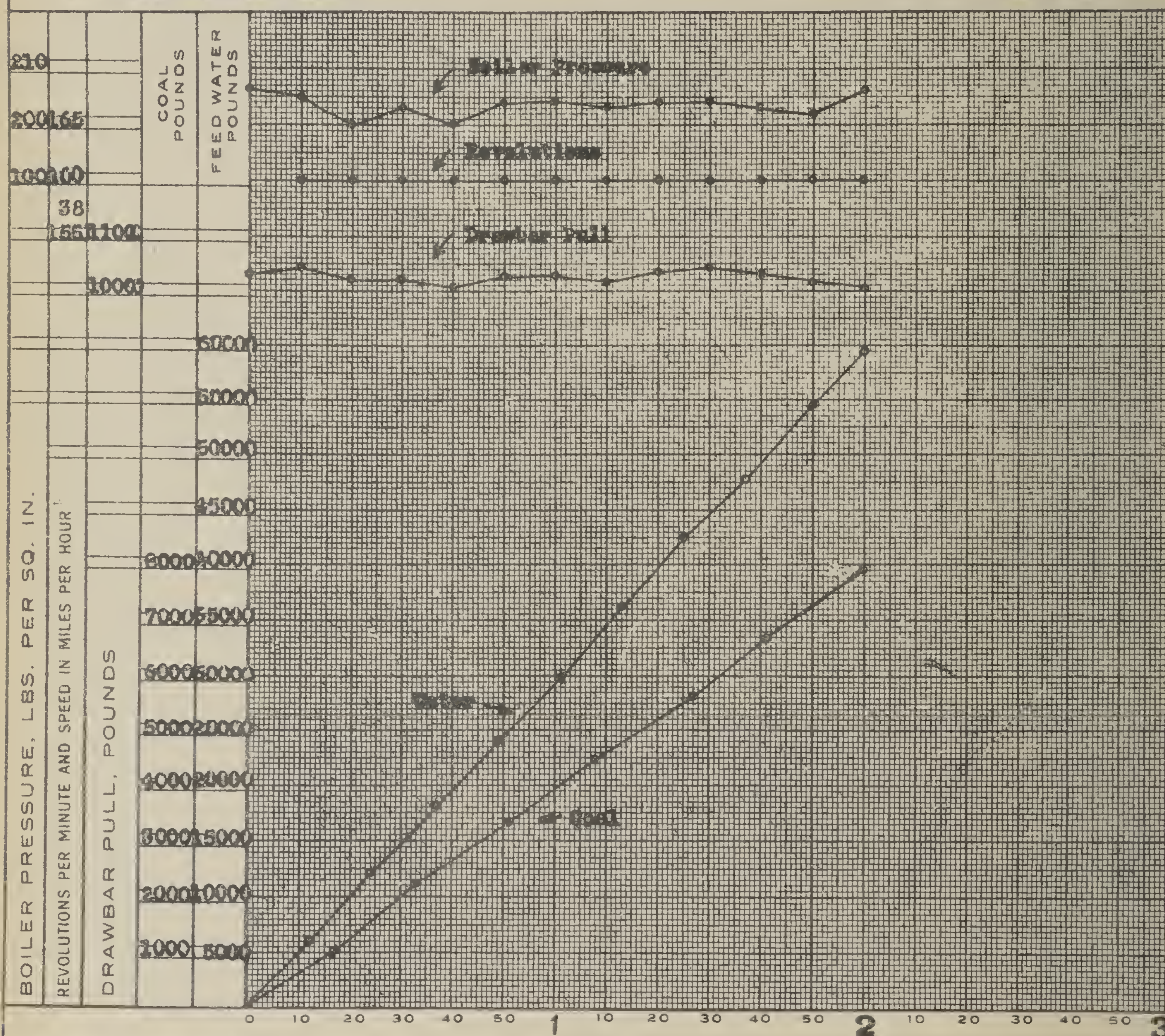
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO **P-340**   TEST DEPARTMENT   **Bulletin** NO. **9**

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End   ALTOONA PA., **9-12-1907**



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE **4-4-2**
CLASS **E2a**
NUMBER **5266**

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	7.5

TEST NO. **900.42**

SHEET NO. **P-340**

M. P. Experimental D-1

12 9 1911
8 x 10½

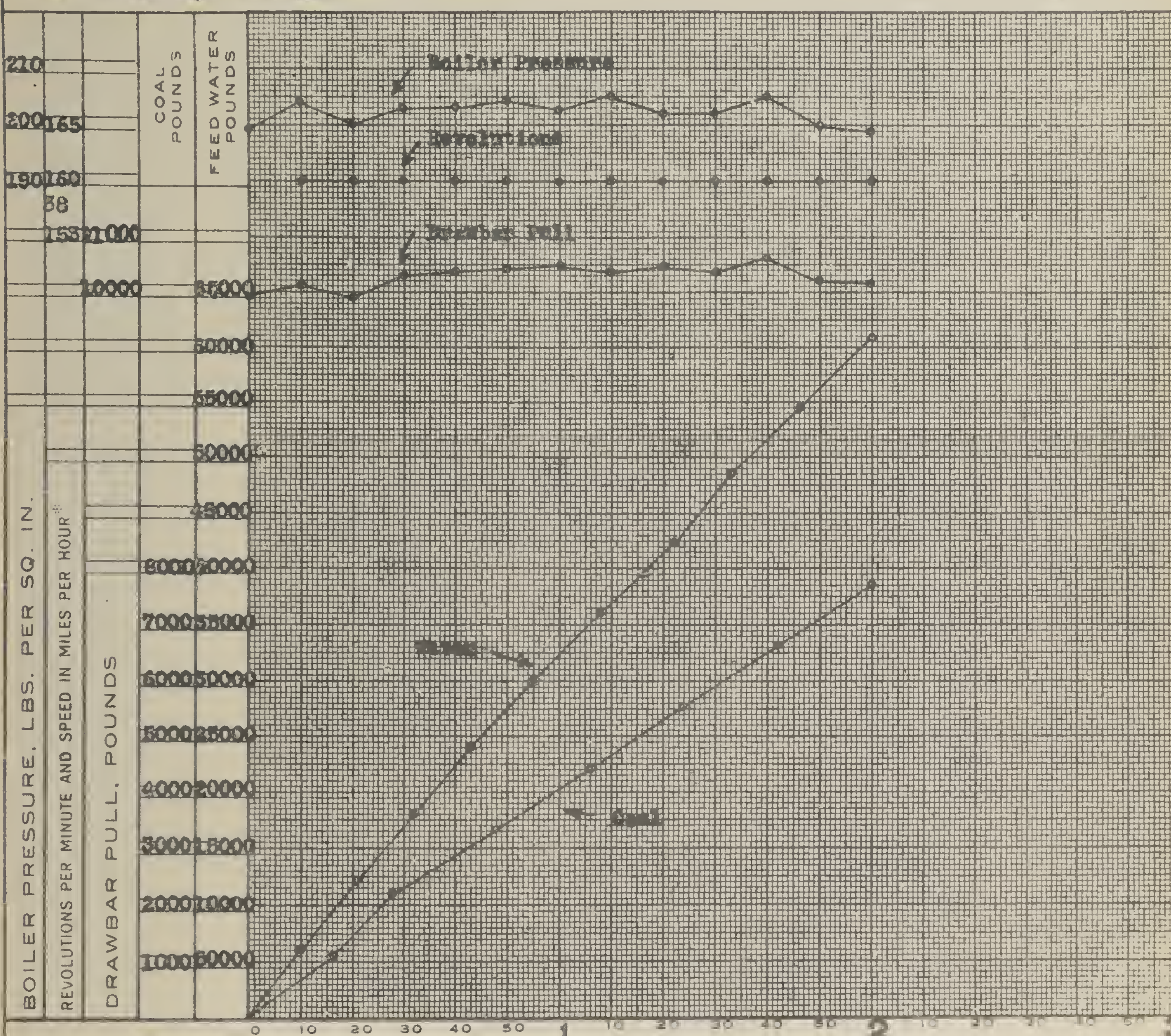
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-341 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 9-14-1907



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE.
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	Full	7.9

TEST NO. 900.44

SHEET NO. P-341

M. P. Experimental D-1

12 9 1911
8 x 10½

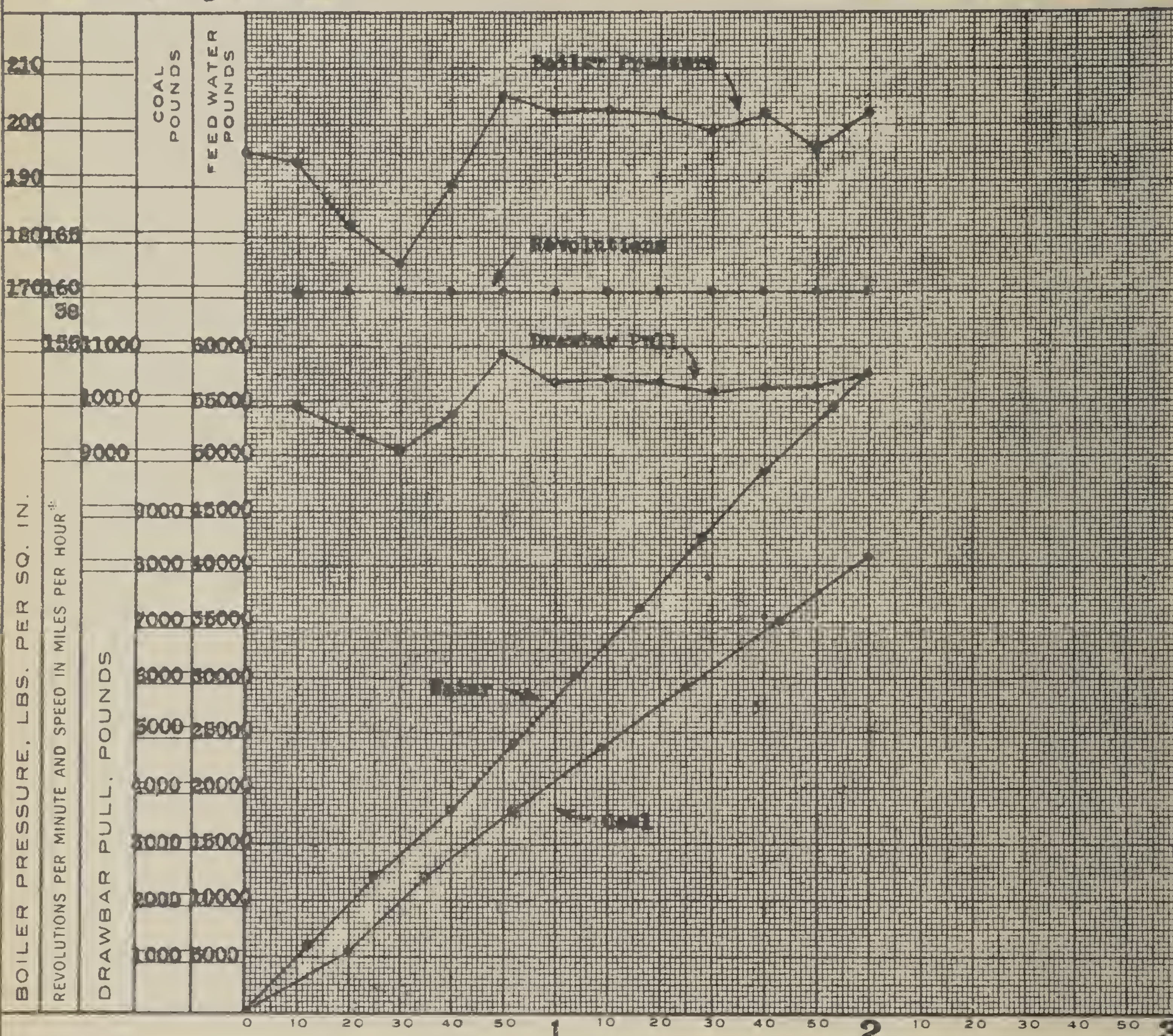
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-342 TEST DEPARTMENT Bulletin No. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 9-19-1907



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E2a
NUMBER 5266

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.6	160	27	F	7.1

TEST NO. 900.47

SHEET NO. P-342

M. P. Experimental. D-1

12 u 1911
8 x 10½

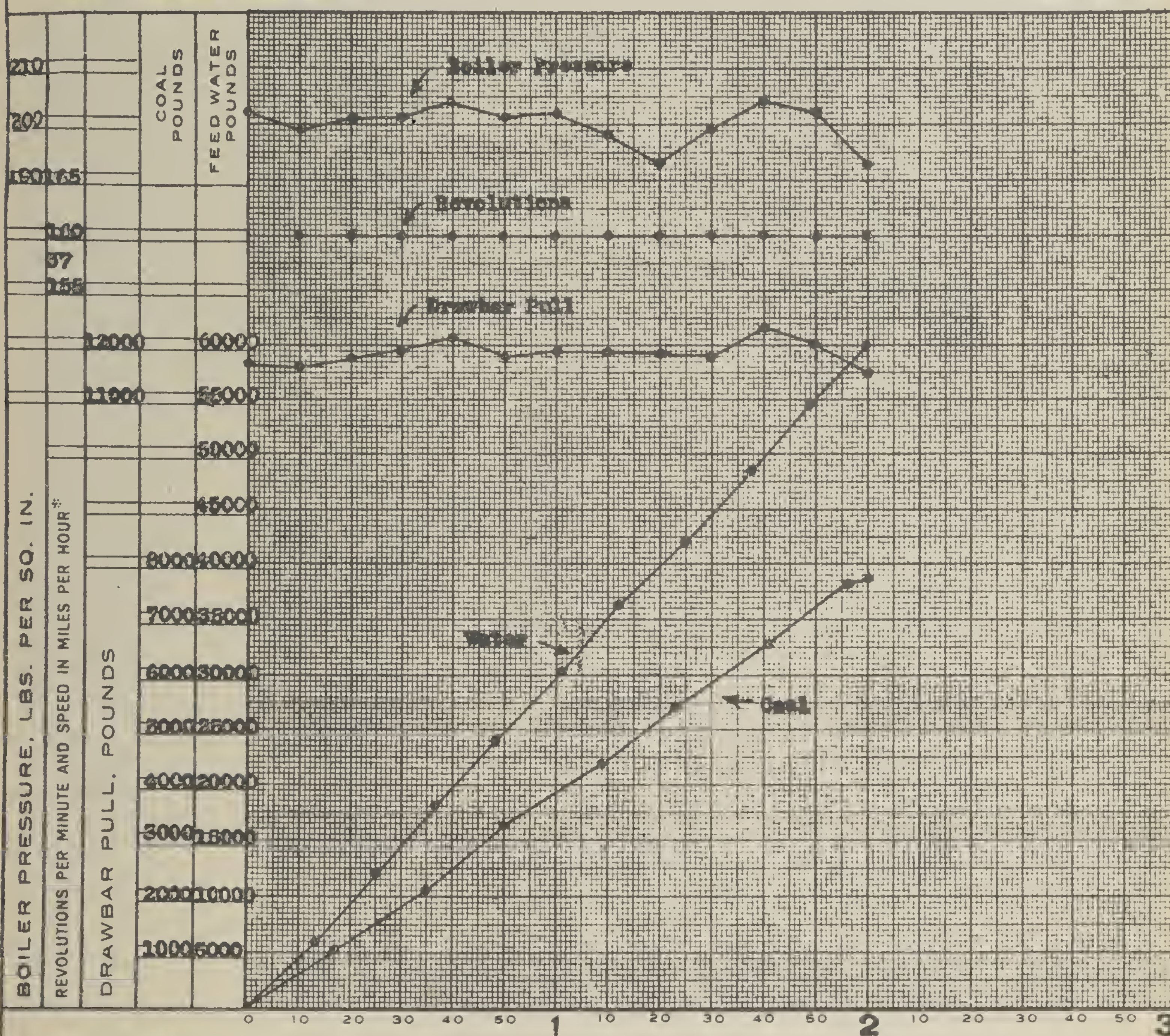
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-343 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA PA., 10-25-1907



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.0	160	25	Full	7.8

TEST NO. 1004

SHEET NO. P-343

M. P. Experimental D-1

12 9 1911
8 x 10½

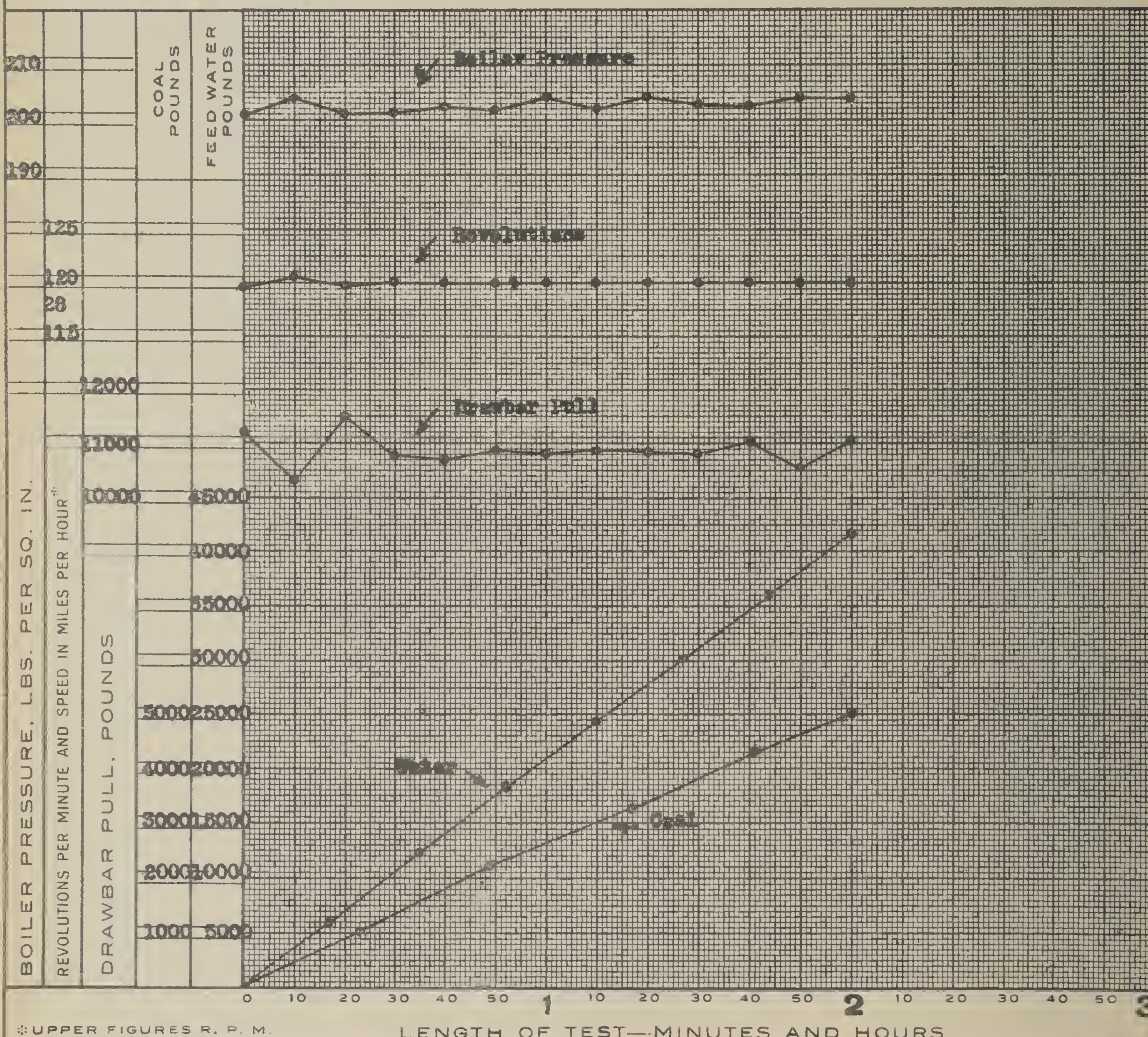
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-344 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 10-30-1907



⁂ UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2994

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
27.8	120	20	Full	8.2

TEST NO. 1005

SHEET NO. P-344

M. P. Experimental D-1

12 9 1911
8 x 10½

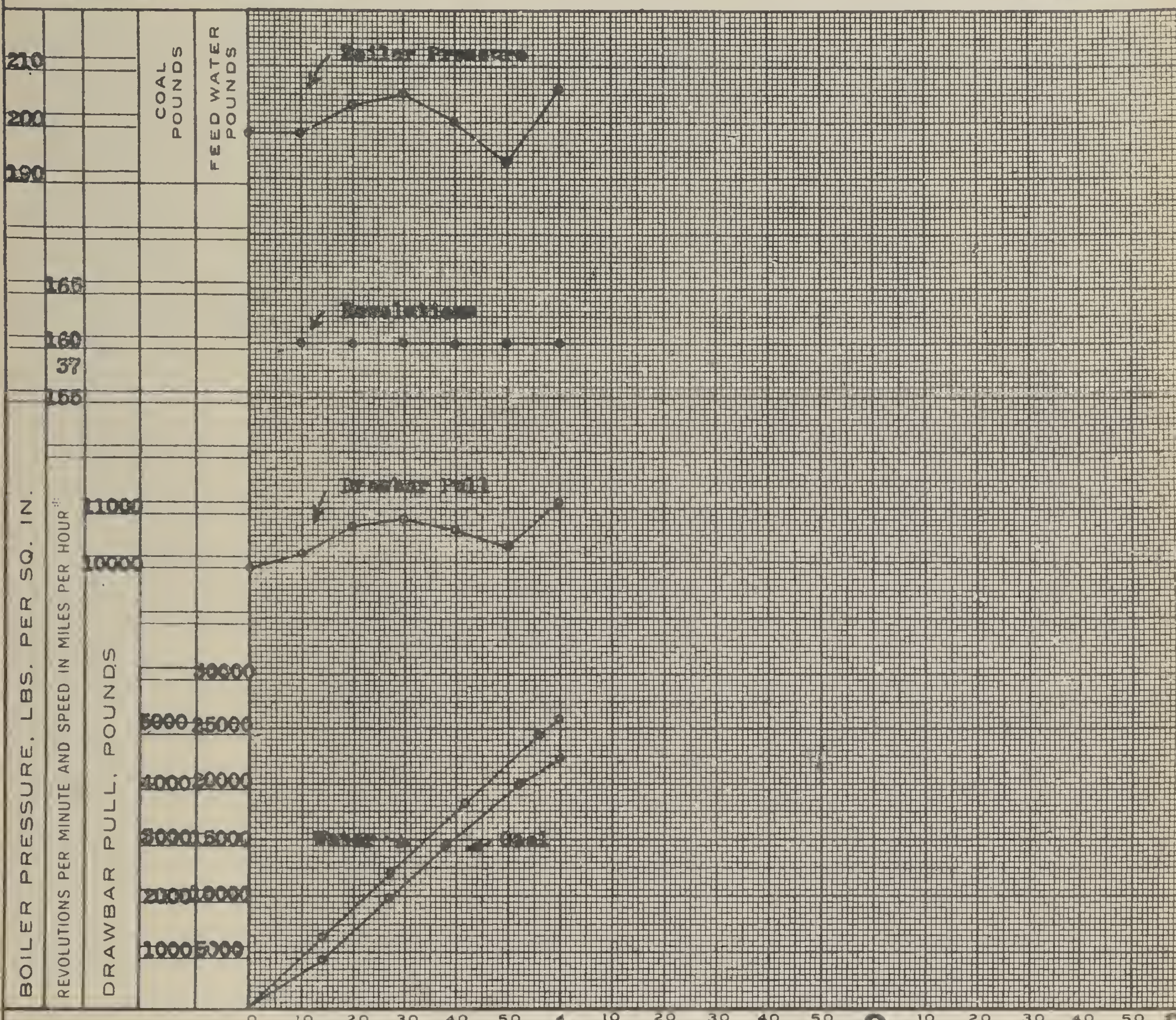
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-345 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 11-4-1907



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
37.0	160	23	Full	5.8

TEST NO. 1007

SHEET NO. P-345

M. P. Experimental D-1

12 9 1911
8 x 10½

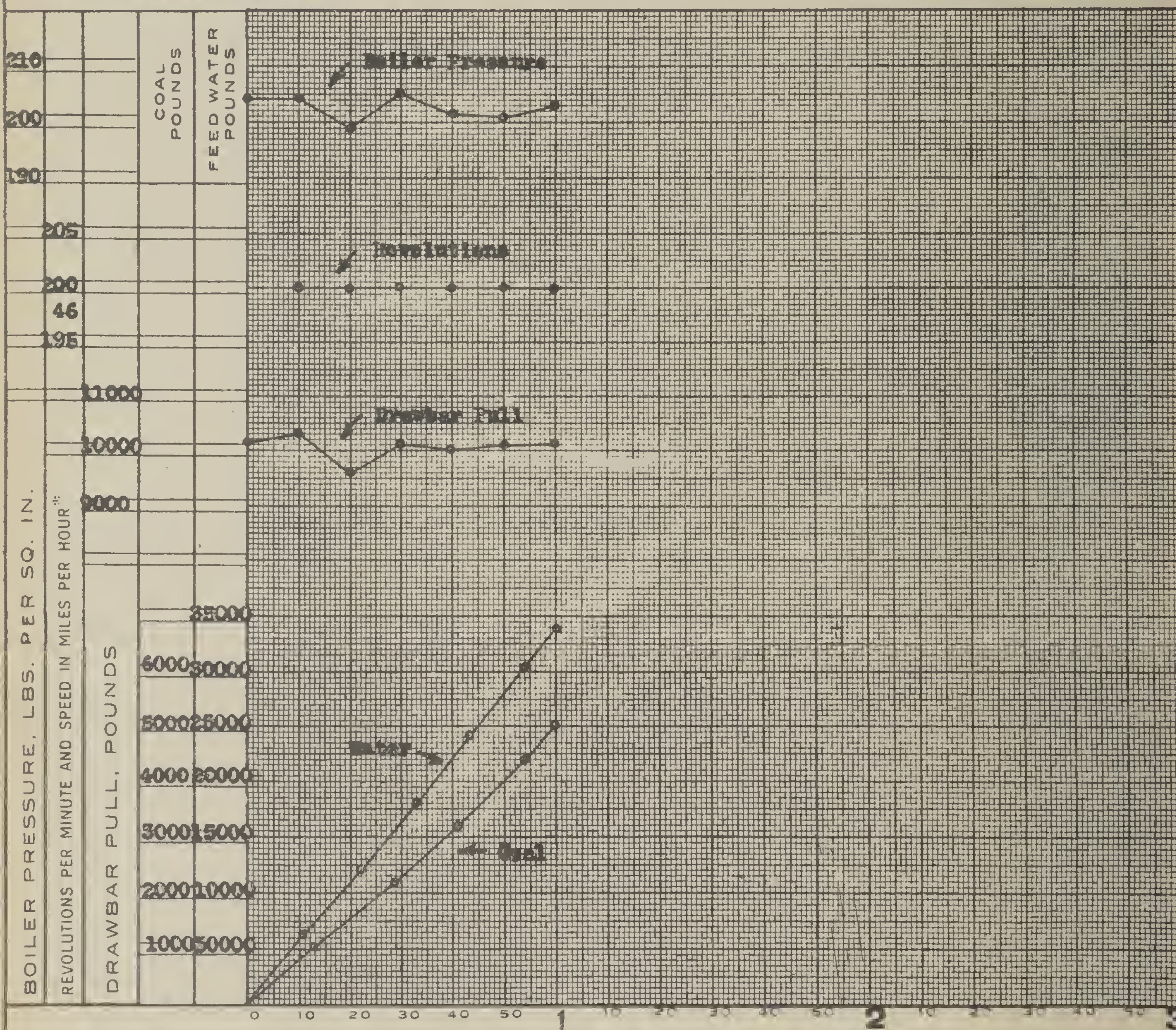
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-346 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., **11-4-1907**



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 4-4-2
CLASS E3a
NUMBER 2984

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
46.3	200	25	Full	6.6

TEST NO. 1008

SHEET NO. P-346

M. P. Experimental D-1

12 x 10½
8 x 10½

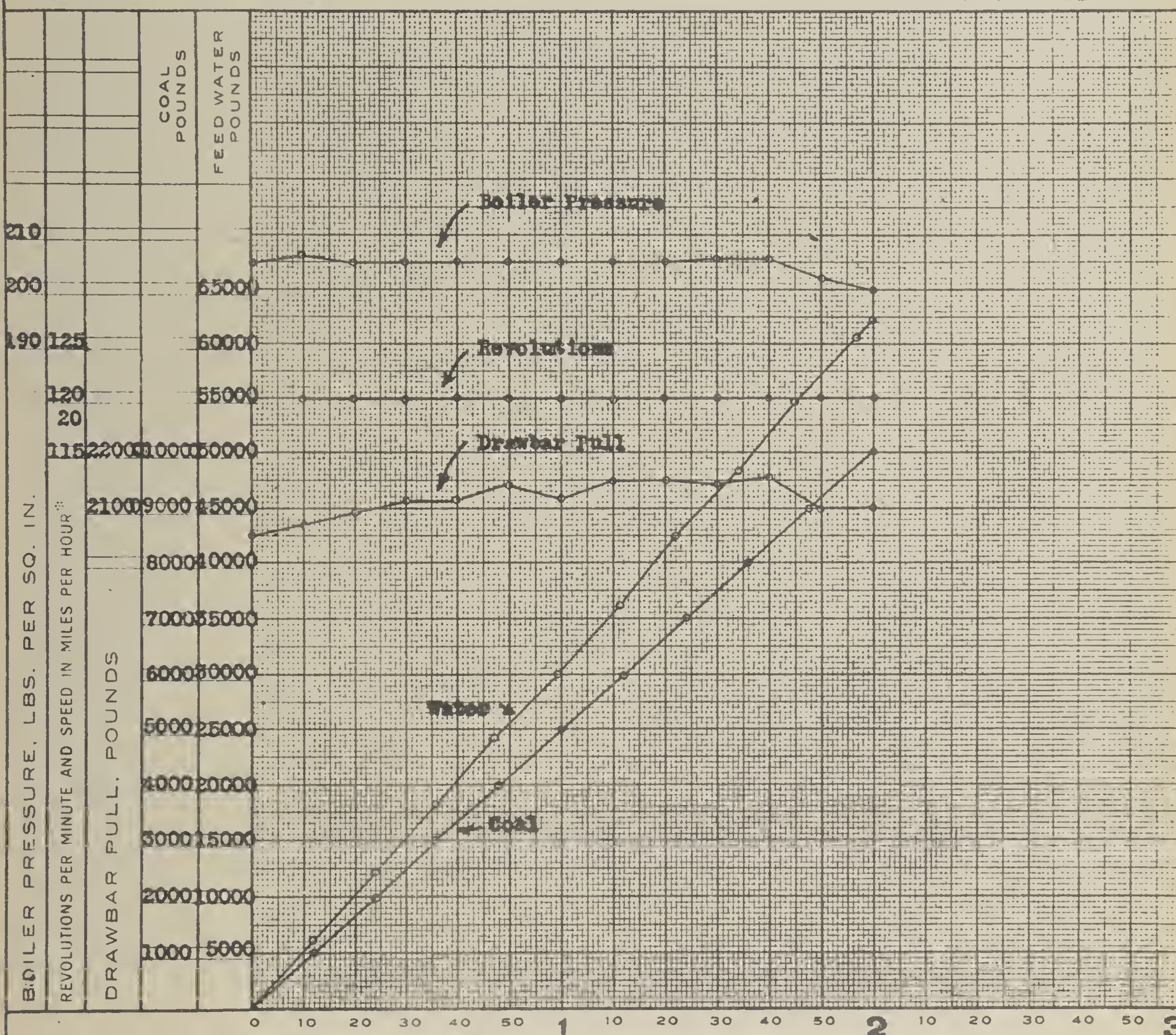
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-347 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA. 5-15-1912



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.5	120	40	F	6.22

TEST No. 1200.275

SHEET NO. P-347

M. P. Experimental D-1

13 9 1911
8 x 10½

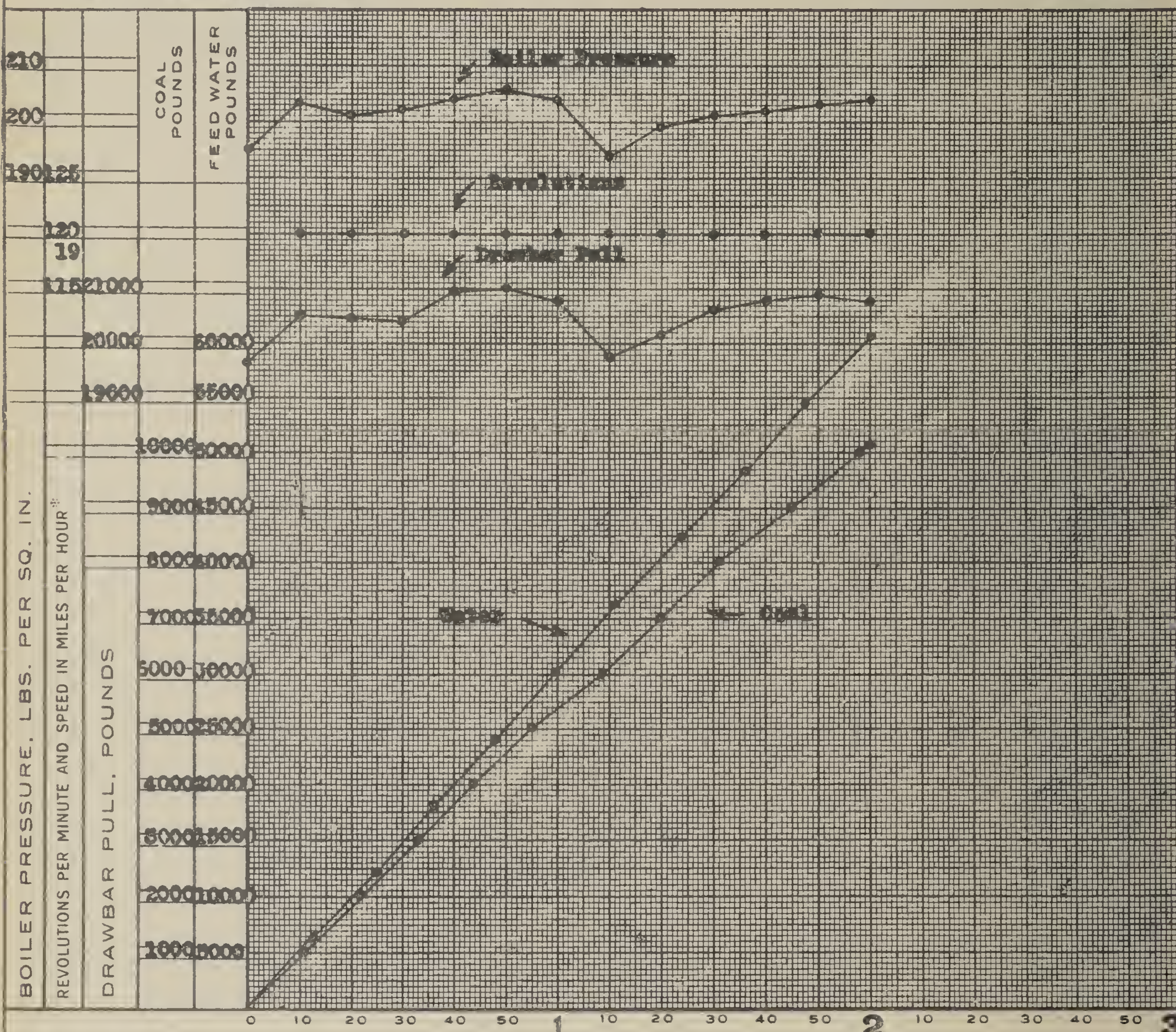
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO P-348 TEST DEPARTMENT **Bulletin** NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 1-4-1910



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.3	120	40	Full	6.1

TEST NO. 1200.425

SHEET NO. P-348

M. P. Experimental D-1

12 9 1911
8 x 10½

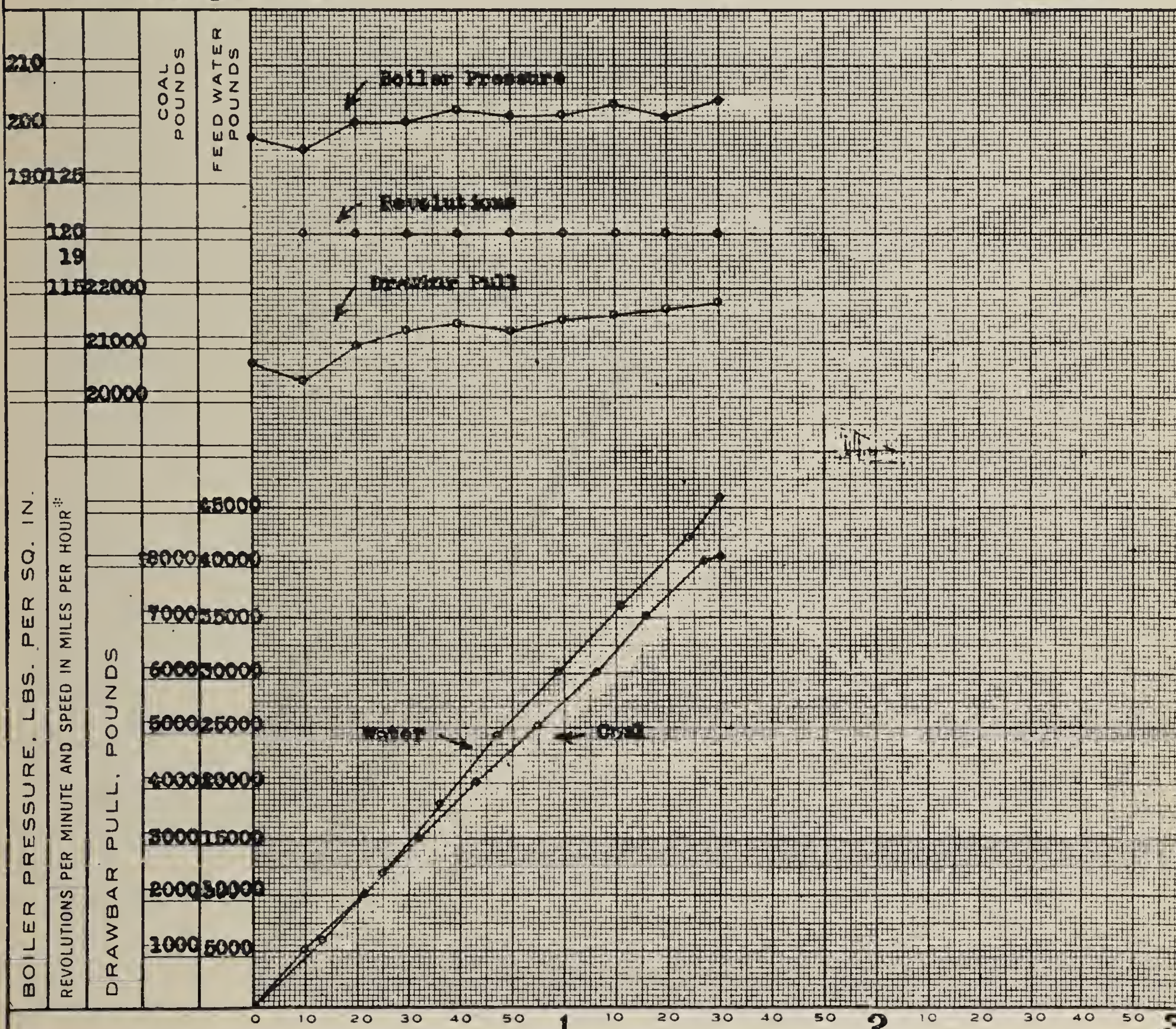
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-349 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 2-2-1910



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.2	120	40	Full	5.7

TEST NO 1200.447

SHEET NO. P-349

M. P. Experimental D-1

12 9 1911
8 x 10½

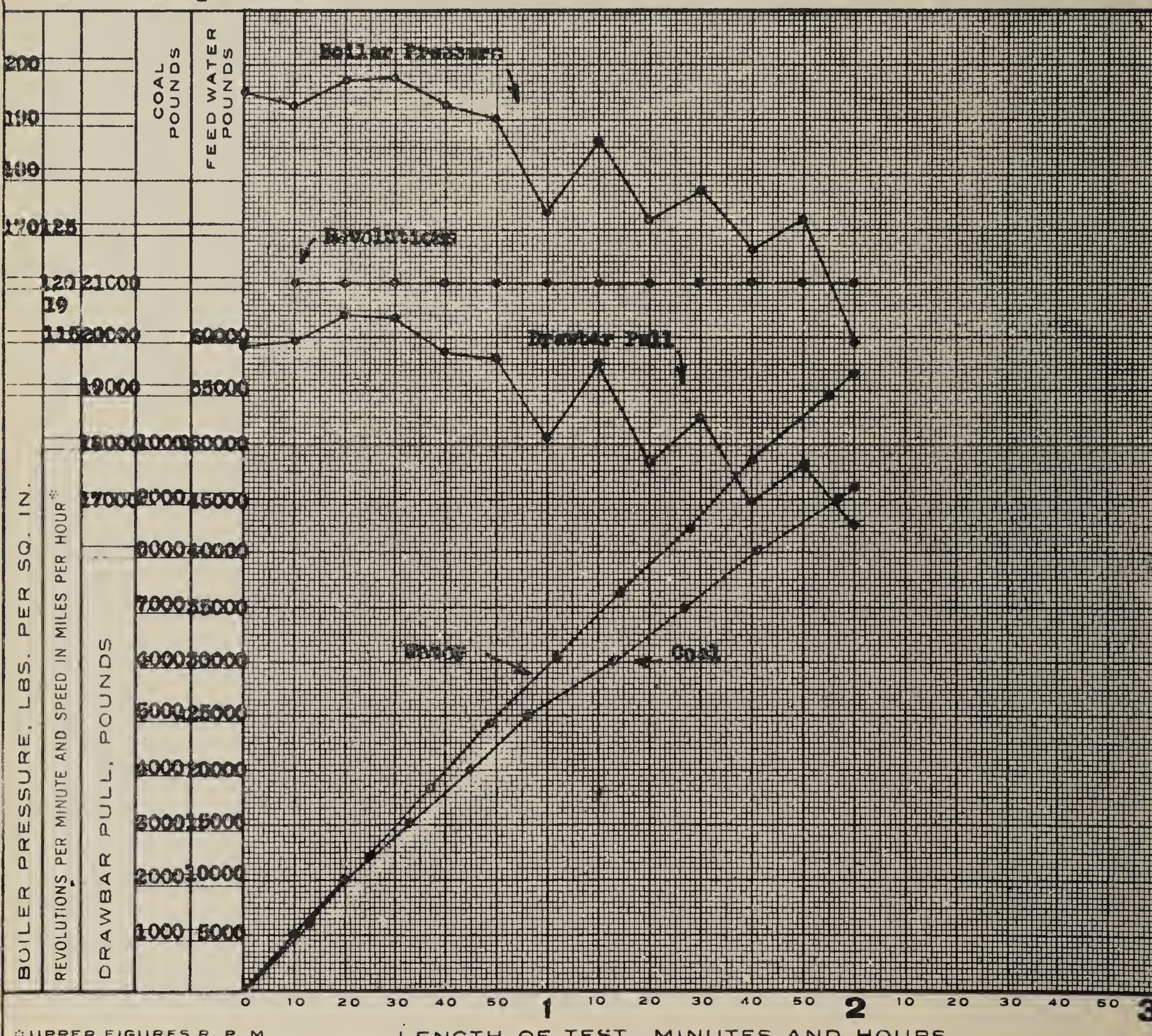
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-350 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 1-25-1910



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.2	120	40	Full	6.1

TEST NO. 1200.439

SHEET NO. P 350

M. P. Experimental D-1

12-11-1911
8 x 10½

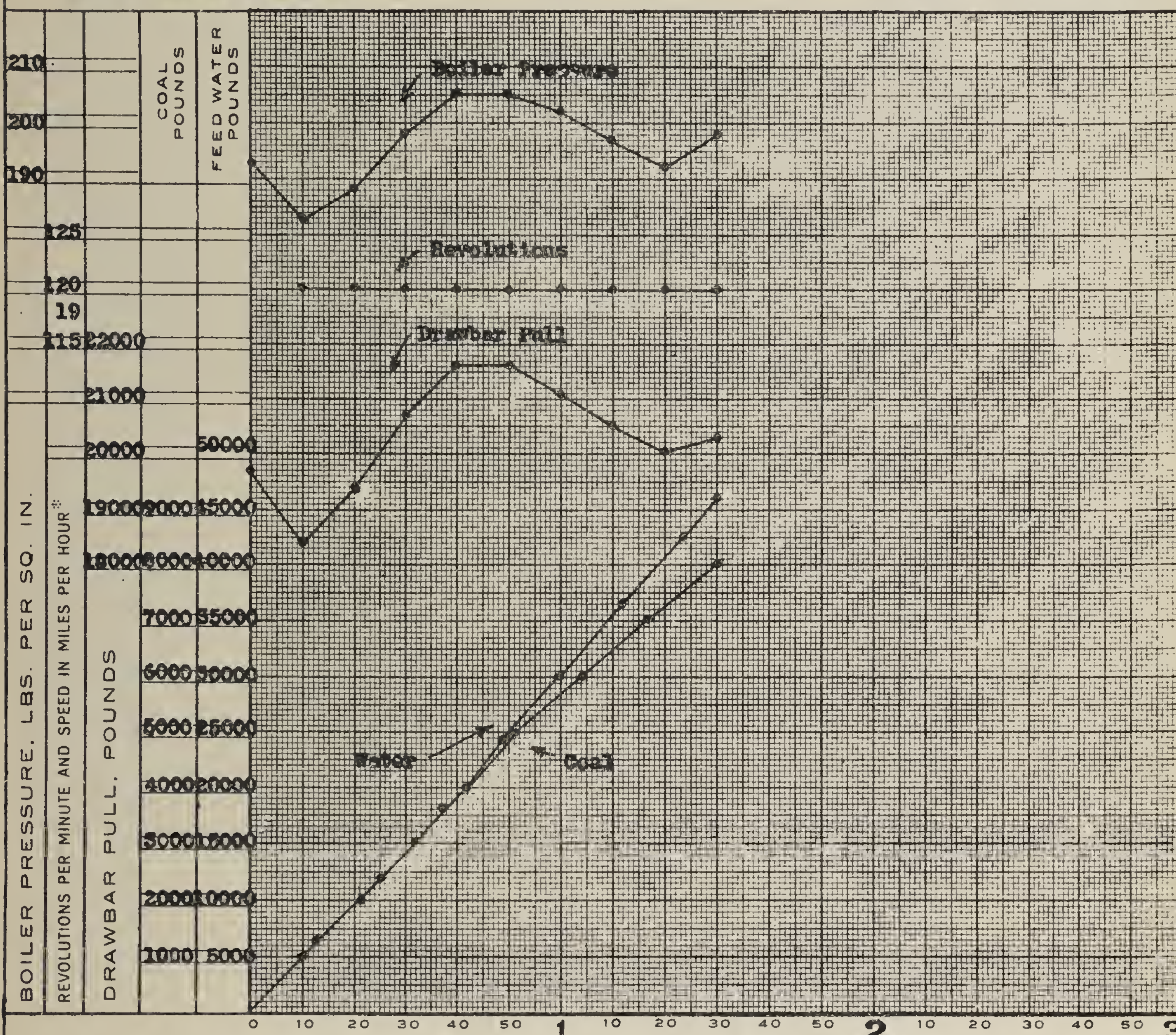
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-351 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 1-10-1910



* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.3	120	40	Full	5.7

TEST NO. 1200-430

SHEET NO. P-351

M. P. Experimental D-1

12 9 1911
8 x 10½

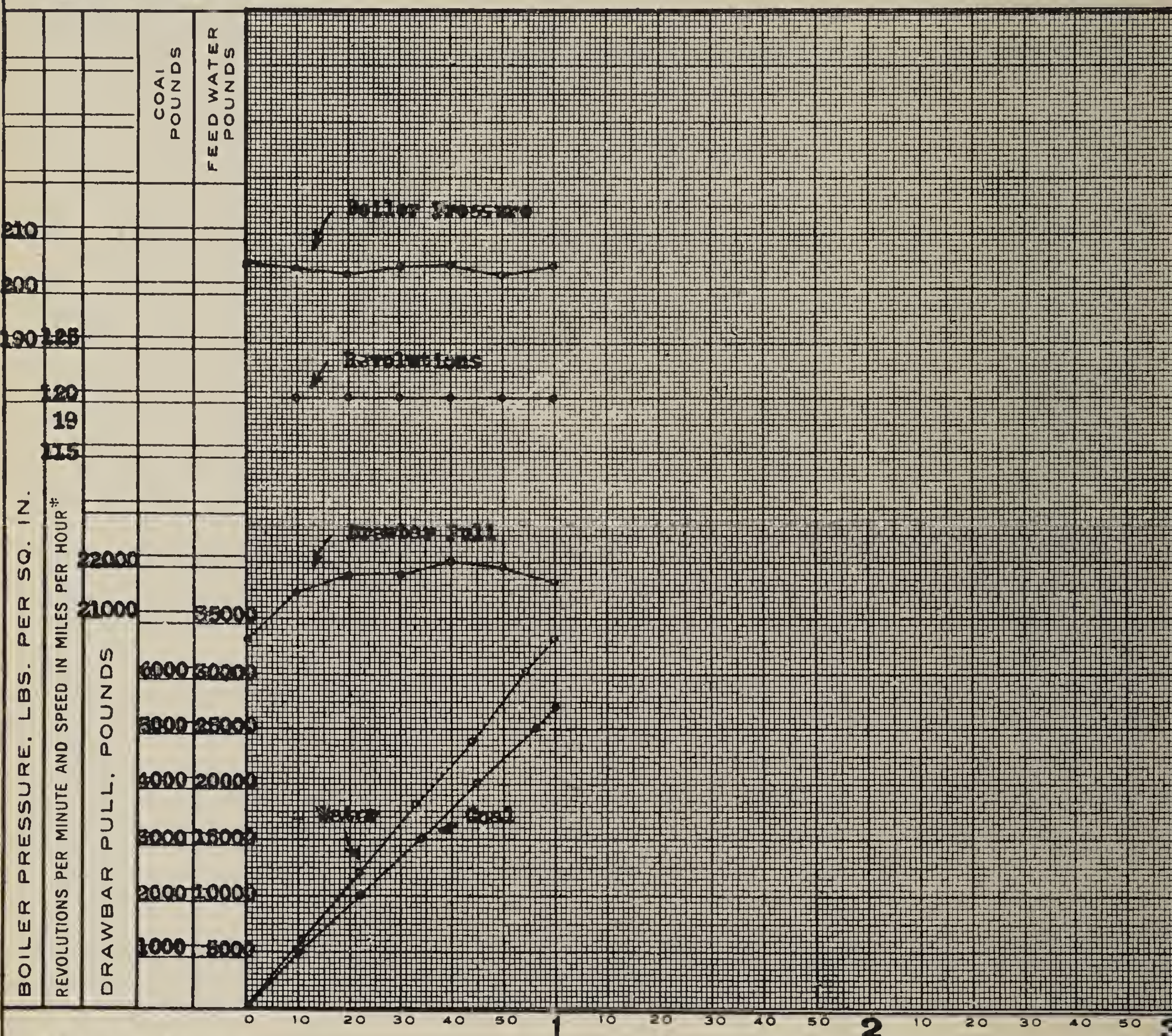
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-352 TEST DEPARTMENT Bulletin NO. 9

GRAPHICAL LOG OF LOCOMOTIVE TEST

Self Cleaning Front End ALTOONA, PA., 1-11-1910



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
19.3	120	45	Full	6.2

TEST NO. 1200.431

SHEET NO. P-352

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 12 (Revised)

Formerly Bulletin No. 15

BANK VERSUS LEVEL FIRING

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1912

THE H6b CLASS LOCOMOTIVE.
The type of locomotive used in the Bank and Level Fire tests.

LOCOMOTIVE TESTING PLANT.

BANK VERSUS LEVEL FIRING

Two methods of Locomotive Firing and the results from a competitive trial under Test Plant conditions.

Conclusions and Recommendations on pages 19 and 20.

INTRODUCTION.

1. This series of trials of level and of bank fires in a locomotive has resulted in a general conclusion that the best practice in firing is to keep the fire level and bright, and at the same time as thin as is possible, in order to carry the load upon the boiler.

2. There are, on the Pennsylvania Lines both East and West, nearly two thousand consolidation locomotives of the H6b class. They have a wide firebox and a nearly level grate. The bituminous coal burned in them is from over one hundred mines, for the most part in Pennsylvania, but extending all the way to the Illinois fields. It is to be expected, with this diversity of coals and the large number of men who fire these locomotives, that differences in method of firing will occur. Firemen are instructed, by the road foreman, to fire by the level fire method, and this method is in general use. It consists in maintaining a fire of uniform thickness over the whole grate, feeding coal to all parts in small quantities so as to have a bright fire over the whole surface and one that is just thick enough to carry the load upon the boiler.

3. Another method is that known as bank firing, and consists in building up, at the back end of the fire, a bank or ridge of fuel, just inside of the firedoor. This ridge of fuel when built up to its full height, has its top at about the level of the top of the firedoor. Coal is fired over the top of this bank and slides down the incline toward the front of the firebox, being assisted by the slope of the grate. It is distributed along the apex of the ridge or bank

and allowed to find its way down to the level portion of the fire at the front end of the grate. The fuel bed under these conditions is not all burning at the same rate but the thick portion or bank is cooler, the more intense fire being at the forward end of the firebox where the fuel bed is thin.

4. The claims of superiority for this method over level firing are: The fuel being heaped up at the rear of the firebox, is coked, the hydrocarbons are driven off slowly and traversing the whole length of the firebox, are burned with little smoke; the bank of green coal, extending up over the door opening, protects the fireman from part of the heat that is radiated from the fire; the work of placing the fuel is simplified, the coal being fed to the top of the bank at a point near the firedoor instead of being distributed over the whole grate surface. These advantages, if real, ought to be capable of demonstration by trial, and in order to make a comparison of bank firing with level firing a series of tests have been made at the Locomotive Testing Plant.

Firemen.

5. The firemen for the tests were selected from men skilled in the use of these two methods of firing. Two of them were strong advocates of the bank fire and had been firing according to this method in their regular road work on the Lines West. Two men were from the divisions where bank firing was practiced on the Lines West, but they believed in and practiced level firing. In addition, there were two Test Plant firemen who were from the Lines East and had become expert in firing by the level fire method. A level fire fireman from the Lines East also assisted in the trial. These firemen will be designated as follows:

B1,	Advocate	of	bank	firing,	Lines	West.
B2,	"	"	"	"	"	"
L1,	"	"	level	"	"	"
L2,	"	"	"		"	"
L3,	"	"	"	"	"	"
T1,	Test	Plant	fireman	level	fire.	
T2,	"	"	"	"	"	
R,	Road fireman level fire Lines East.					

The Locomotive.

6. The tests were made with an H6b class locomotive 2860. A drawing of this locomotive is shown in Fig. 1. Table 3 gives the principal dimensions. There was no arch in the firebox. The grate is long and wide (8 feet $10\frac{1}{2}$ inches long and 5 feet 6 inches wide) and nearly level.

7. There are drop grates at the front and rear, with 18 sections of shaking grate bars between. The grate area is 48.66 square feet. The air openings through the grate have a total area of 17.6 square feet or 36.4 per cent. of the grate.

The Coal.

8. The coal used was of two kinds. In the first three tests, Nos. 1275 to 1277, coal from the Pennsylvania and Northwestern region in Pennsylvania was used. This is a high carbon bituminous coal, with little ash, and will be designated as Eureka No. 6. It is fairly representative of the coal used on the Lines East, in the H6b locomotive.

9. For the remaining tests, coal from the Pittsburgh Coal Company was used. This is known as No. 8 Pittsburgh Steam Coal. It is a high volatile coal with a rather high amount of ash. This coal is used on the Lines West.

An analysis of each coal shows the following:

	Eureka "No.6"	*Pittsburgh Coal Co.*
Fixed carbon, per cent.	60.10	48.17
Volatile combustible, per cent.	30.36	36.37
Moisture, per cent.	0.74	2.04
Ash, per cent.	8.80	13.42
	100.00%	100.00%
Sulphur determined separately,	2.08	3.18
Calorific value, B. t. u. per pound dry,	13743	12364

The Level Fire.

10. The methods used in firing the level fire were much the same in the case of each of the level fire firemen. The coal was broken rather fine, to two inches in thickness or less, and was fired in single shovelfuls or at a uniform rate. Fig. 2 shows the probable appearance of a section of the level fire on the grate.

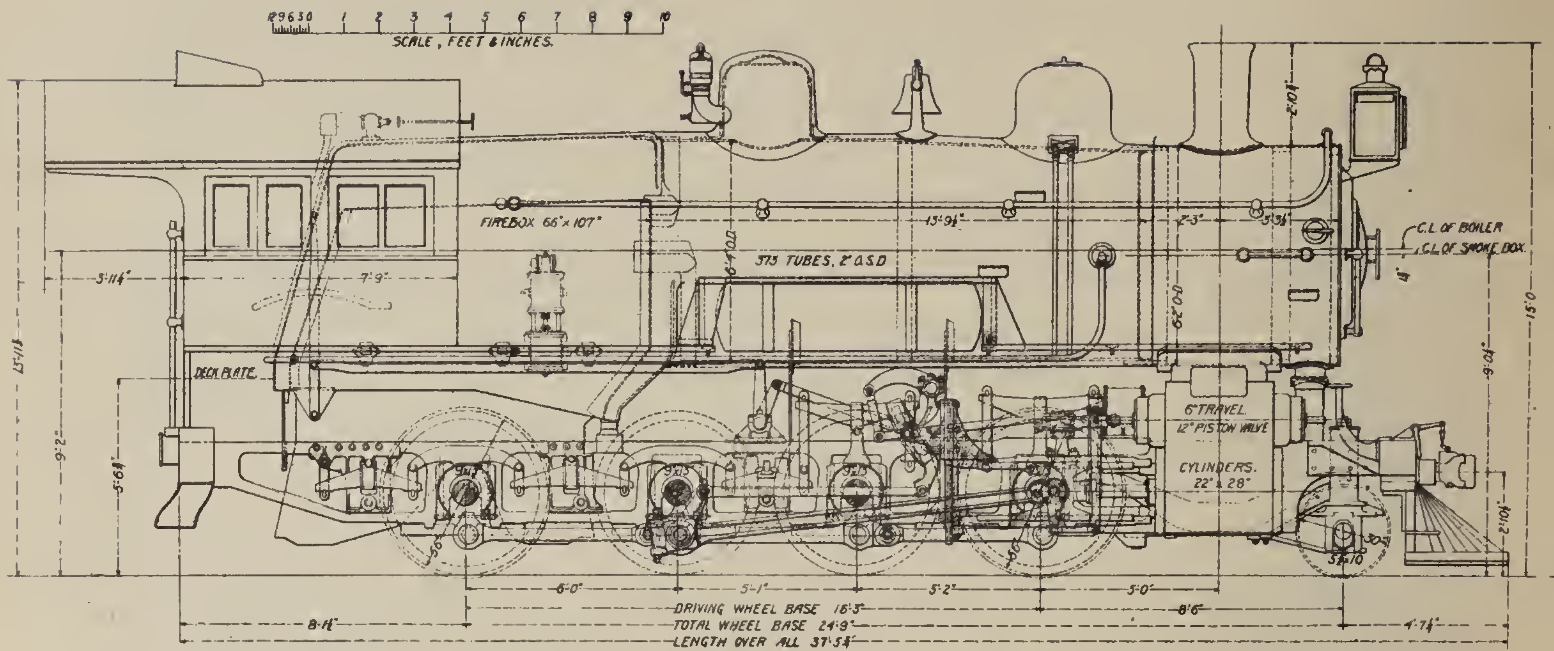


Fig 1.

CLASS H6b LOCOMOTIVE.

The Locomotive used in the Tests.

THE LEADING DIMENSIONS OF THE "H6b" LOCOMOTIVE ARE AS FOLLOWS:

Total weight, pounds	198,267
Weight on drivers, pounds	176,600
Cylinders (simple), inches	22x28
Diameter of drivers, inches	56
Firebox heating surface, square feet	166.4
Heating surface in tubes (water side), square feet	2673.68
Total heating surface (based on water side of tubes), square feet	2839.74
Total heating surface (based on fire side of tubes), square feet	2505.29
Grate area, square feet	48.66
Boiler pressure, pounds	205
Valves	American, Stayman and "L" type
Valve motion	Walschaerts
Firebox, type	Belpaire
Number of tubes	373
Outside diameter of tubes, inches	2
Length of tubes, inches	164.28

The maximum tractive effort is 39,773 pounds, which is calculated on the assumption that 80 per cent. of the boiler pressure (205 pounds) is available as mean effective pressure at starting.

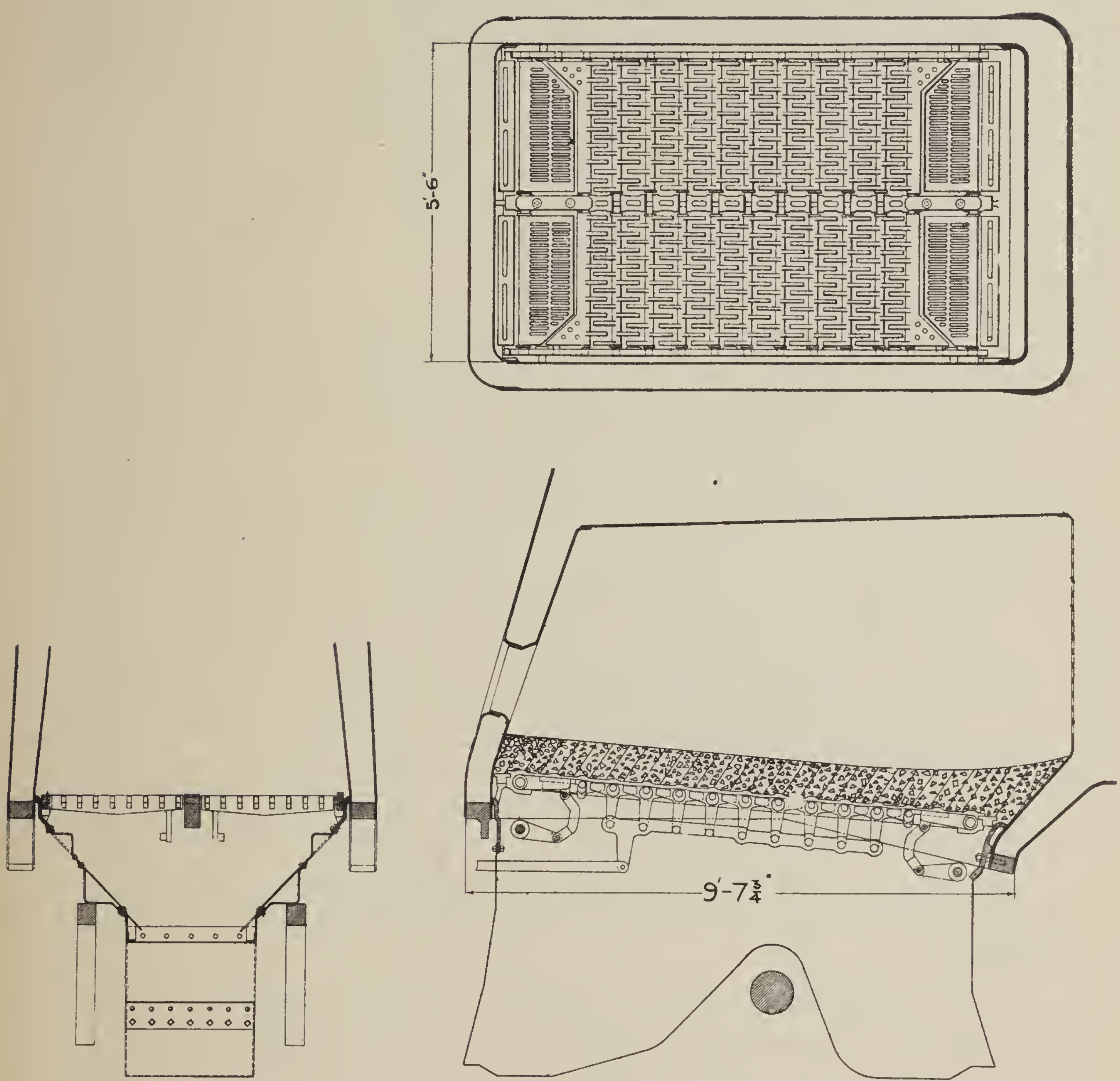


Fig. 2.

LEVEL FIRE.

A plan of the grate and a longitudinal section are shown.

The Bank Fire.

11. The bank-fire fireman did not follow strictly the method of firing the bank fire as given above. A low bank, as shown in Fig. 3, was built up, but with the exception of test No. 1278, the bank served only as a partial protection from the heat and glare of the fire, the coal being fired in small quantities and uniformly over the entire grate, except over the bank. The bank top was about 18 inches inside of the firedoor, and with the bank so low that on this practically level grate it is evident the coal would not slide by gravity to the front of the firebox. In test No. 1278 an attempt was made to fire by placing all of the coal on the top of the bank. The top of the bank in this case was about $3\frac{1}{2}$ feet inside of the firedoor and the fire at the front of the firebox was very thin.

The Tests.

12. The tests were made at speeds of 80 revolutions per minute, about 13 miles per hour, and at 100 revolutions, about 17 miles per hour, with wide open throttle and were two and one-half hours long, except in two cases.

13. In bank-fire tests Nos. 1277 and 1278 the same man fired throughout, but in the other bank-fire tests the fire was prepared by the Test Plant fireman and, at the instant of starting the test, turned over to the bank fireman to build up the bank and continue firing to the end of the test. Just before the end of these later bank-fire tests the bank was allowed to burn down. This was done in order, and in a way to make sure that the condition of the fire would be the same at the end of the test as at the start, so that the coal supply could be accurately weighed. The bank would be burned out in less than seven minutes. All of the firing, both level and bank, was continuous, small quantities being fired at one time and the coal was broken down before firing.

14. In Tables 1 and 2 a summary of the results of the tests is given. The tests in Table 1 were run at a speed equivalent to about 13 miles per hour and a cut-off of 40 per cent., giving an evaporation of about 11 pounds of water per square foot of

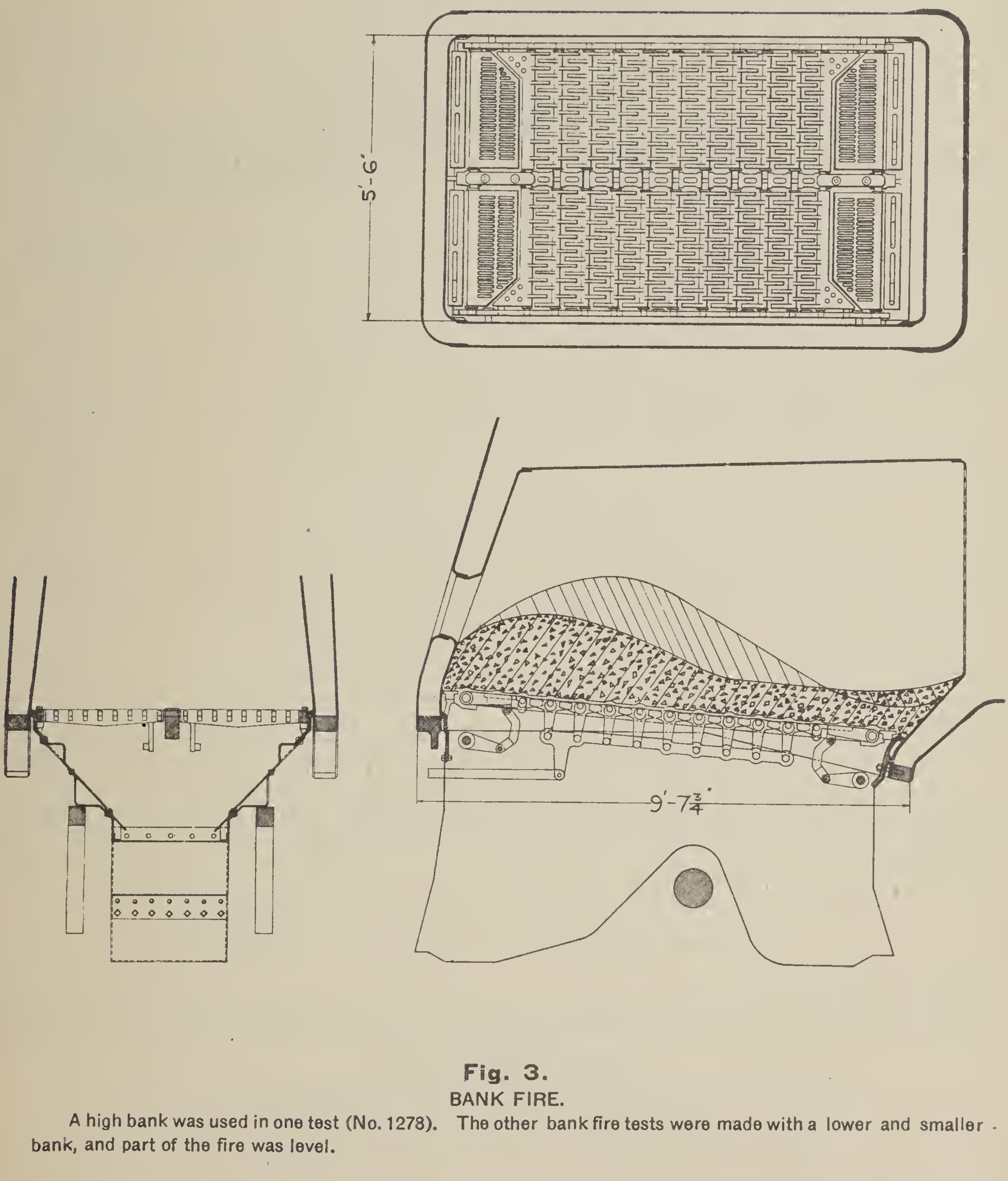


Fig. 3.

BANK FIRE.

A high bank was used in one test (No. 1278). The other bank fire tests were made with a lower and smaller bank, and part of the fire was level.

M. P. 479—A

8 x 10½
851 4-29-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b No. 2860

SHEET No. P-460

Bank Versus Level Firing

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 12

ALTOONA, PA. 11-22-1912

TABLE 1

EVAPORATION AND SMOKE

WEST EUREKA NO.6 COAL

Test Number	Miles per Hour	Cut Off	throttle.	Boiler Pressure Avg.	Equivalent Evaporation From and at 212°F. Per Sq.Ft. Heat Surf. Per Hour	Equivalent Evaporation From and at 212°F. Per Pound of Dry Coal	Relative Evap. in per cent Best Evap. equals 100%	Carbon Monoxide in Gases Average	Smoke in percent Average	Kind of Fire
				1	2	3	4	5	6	7
1276	13	40	Full	197.4	10.84	8.33	91.8	0.35%	28	Level
1275	"	"	"	201.6	11.36	9.07	100.0	0.60	36	"
Average							95.9			
1277	"	"	"	202.0	11.07	9.04	99.7	0.95	28	Bank
Average							99.7			
PITTSBURGH COAL COMPANY COAL										
1285	13	40	Full	202.3	10.88	8.68	91.9	0.10	24	Level
1288	"	"	"	201.0	10.86	9.17	97.0	--	32	"
1284	"	"	"	203.3	11.08	9.18	97.1	—	28	"
Average							95.3			
1286	"	"	"	203.3	11.09	8.66	91.6	0.35	28	Bank
1287	"	"	"	202.9	11.04	9.45	100.0	0.10	24	"
Average							95.8			

SHEET No. P-460

Table 1.
EVAPORATION AND SMOKE.
The tests in this table were made at 13 miles per hour.
Column 4 shows a comparison based upon evaporation per pound of coal.
From this standpoint the bank fire is the best.

M. P. 479—A

8 x 10½
351 4-29-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b No. 2860

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 12

SHEET NO. P-461

Bank Versus Level Firing ALTOONA, PA. 11-15-1912

TABLE 2

EVAPORATION AND SMOKE

PITTSBURGH COAL COMPANY COAL.

Test Number	Miles per Hour	Cut off	throttle.	Boiler Pressure Avg.	Equivalent Evaporation From and at 212°F. Per Sq.Ft. Heat Surf. Per Hour	Equivalent Evaporation From and at 212°F. Per Pound of Dry Coal	Relative Evap.in per cent Best Evap. equals100%	Carbon Monoxide in Gases Average	Smoke in percent Average	Kind of Fire
				1	2	3	4	5	6	7
1279	17	45	Full	197.7	14.89	7.35	83.2%	1.05%	48	Level
1283	"	"	"	199.7	14.85	7.72	87.4	1.30	42	"
1289	"	"	"	200.3	14.59	8.07	91.4	0.15	30	"
1290	"v	"	"	198.4	14.59	8.14	92.2	0.35	38	"
1293	"	"	"	197.3	14.29	8.53	96.6	0.80	34	"
1281	"	"	"	202.0	15.07	8.57	97.1	0.45	40	"
Average							91.3			
1278	"	"	"	193.5	14.21	6.89	*78.0	0.30	52	Bank
1292	"	"	"	198.7	14.66	7.82	88.6	0.85	42	"
1282	"	"	"	200.5	14.88	7.99	90.5	0.70	46	"
1280	"	"	"	201.8	15.07	8.16	92.4	0.45	50	"
1291	"	"	"	200.5	14.51	8.83	100.0	0.00	28	"
Average							89.9			
Average							∅ 92.8			

* 3-1/2 Foot Bank; the other tests are with an 1-1/2 Foot Bank.

∅ Omitting Test 1278 which has an excessively high bank.

SHEET NO. P-461

Table 2.

EVAPORATION AND SMOKE.

These tests were made at 17 miles per hour. If test No. 1278 (the real bank fire) is included, the average results for the bank fire are low.

heating surface per hour. The tests in Table 2 were run at a higher speed, 17 miles per hour and 45 per cent. cut-off, giving an evaporation of between 14 and 15 pounds of water per square foot of heating surface per hour.

15. These conditions did not make a very heavy demand upon the boiler for steam with these coals, as with the Eureka No. 6 coal we have obtained in other tests on the Plant an equivalent evaporation of 16½ pounds of water per square foot of heating surface per hour.

16. In column 4 of Tables 1 and 2 a comparison is made between the evaporation obtained by the different firemen. The highest evaporation for each group of tests is taken at 100 per cent.

17. Considerable differences are shown between the level fire firemen. It is very clear too, that the second test made by some of the men shows a very decided improvement over the first trial on the Test Plant.

18. In the case of fireman B1, with a bank fire, in test No. 1278, an evaporation of 6.89 pounds per pound of coal is shown, while on the next test, No. 1282, made by the same fireman, an evaporation of 7.99 pounds was obtained, an increase of about 14 per cent. and a saving of 961 pounds of coal in the second test. This would be a saving of about 2800 pounds over a 100 mile division.

Temperature Near Firedoor.

19. At a point near the firedoor a thermometer was suspended and observations of the temperature were made for each kind of firing, with the following results:

In test No. 1283, level fire, the temperature was	117° F.
" " " 1281, " " " " "	114° F.
Average	116°

In test No. 1282, bank fire, the temperature was	104° F.
" " " 1280 " " " " "	94° F.
Average	99°

There is here an average difference of 17 degrees between the bank and level fire.

Evaporation Per Pound of Coal.

20. On diagrams Fig. 4 and Fig. 5 the results of the tests are plotted to show the evaporation per pound of coal.

21. In the tests at 100 revolutions per minute the range of coal fired per square foot of grate is from 85 to over 105 pounds. The best results, or highest evaporation per pound of coal, are for the bank fire as fired by fireman B2. These tests are Nos. 1287 and 1291, and it will be noted that they were the last tests fired by this fireman, showing that this fireman improved in his firing by experience at the Plant. Fireman T1 and T2 in addition to their road firing had had considerable experience at the Plant, firing, between them, seventy-five tests, and the results of their work with the level fire are very close together. At 100 revolutions per minute, the difference in the evaporation per pound of coal between the tests Nos. 1281 and 1293, by these two firemen, is but four-hundredths of a pound. At 80 revolutions per minute, fireman T1 duplicates his two tests, Nos. 1275 and 1288, within one-tenth of a pound.

Smoke.

22. Observations of the smoke by the Ringelmann method were made at 10 minute intervals during each test, and the results are conflicting. (See Tables 1 and 2.) With Eureka coal at 13 miles per hour the level fire shows the most smoke. At the same speed and Pittsburgh coal the level fire again shows the most smoke. At 17 miles per hour with Pittsburgh coal the bank fires show the most smoke.

Gas Analysis.

23. The amount of carbon monoxide (CO) in the smokebox gases is dependent upon the completeness of the combustion, a large amount of CO indicating insufficient air supply and consequent incomplete combustion.

24. An inspection of the smokebox gas analysis does not show any marked difference between the two methods of firing. The least quantity of CO was obtained in bank fire test No. 1291.

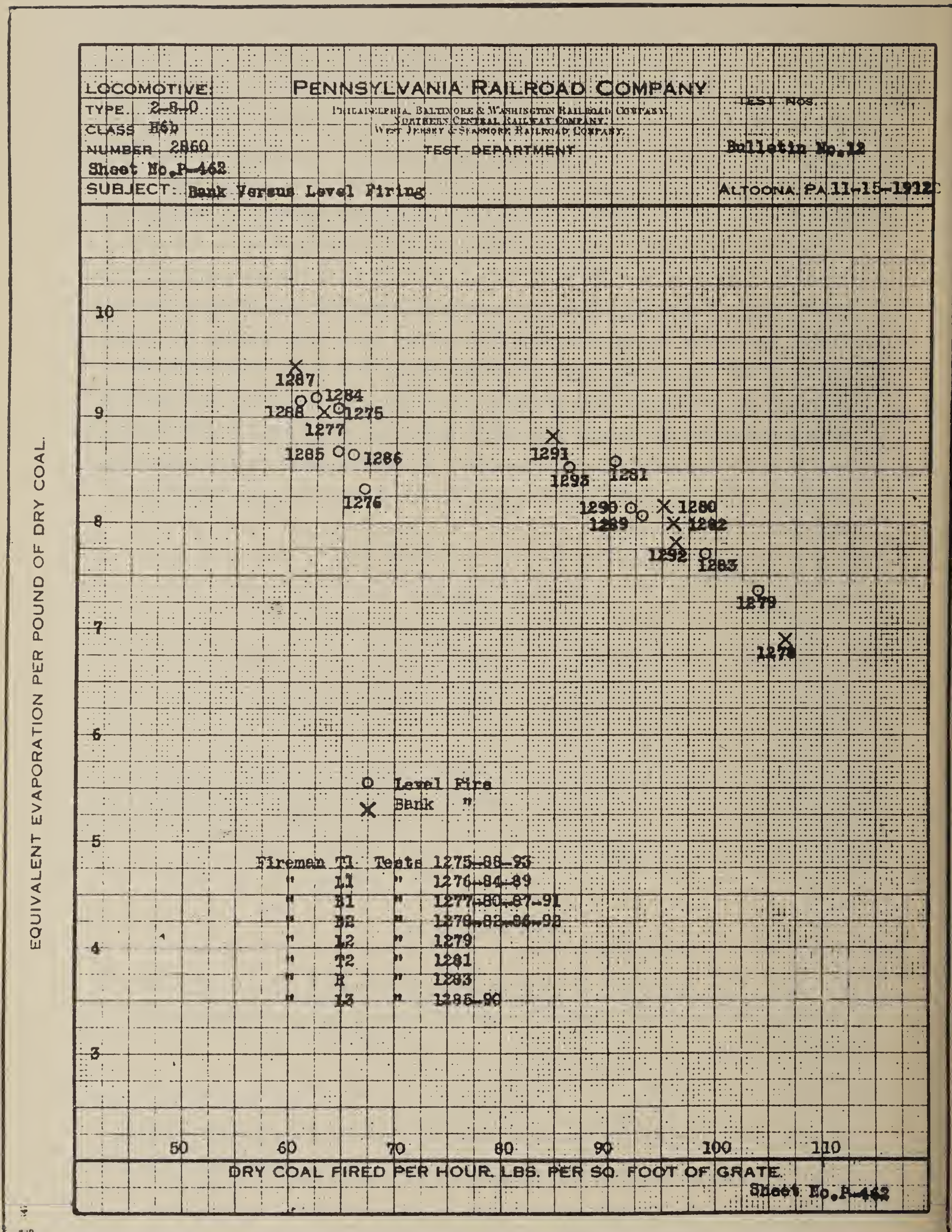


Fig. 4.

EVAPORATION PER POUND OF COAL AND RATE OF FIRING.

The test number is shown for each point. The results are influenced more by the skill of the fireman than by the method of firing.

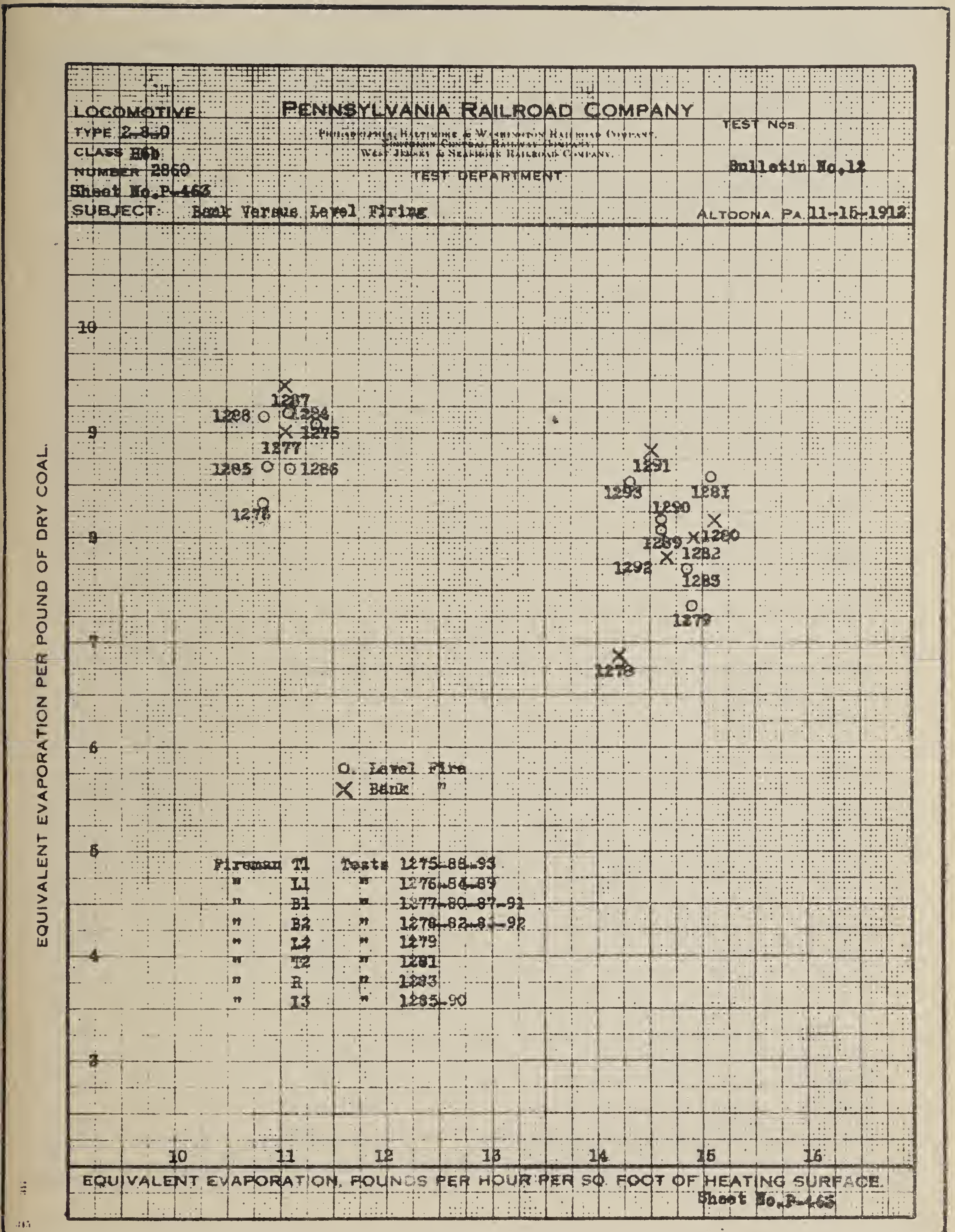


Fig. 5.

EVAPORATION PER POUND OF COAL AND RATE OF EVAPORATION.

Under the same conditions of running, there is much difference in the results with the different firemen regardless of the method of firing.

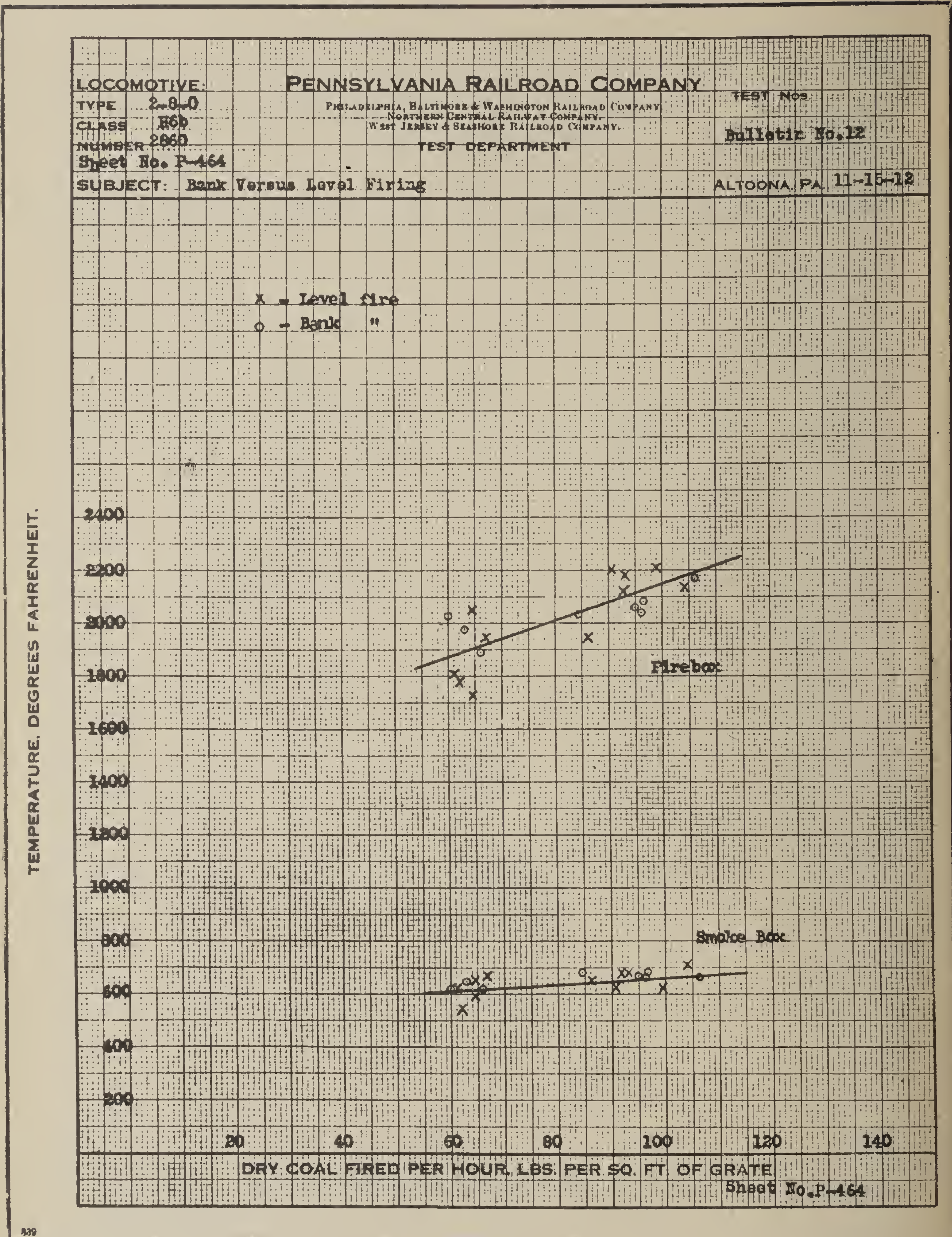


Fig. 6.

TEMPERATURES IN FIREBOX AND IN SMOKEBOX.

There is no apparent difference in temperature due to the method of firing.

Draft and Thickness of Fire.

25. The intensity of the draft at any speed and cut-off depends upon the thickness of the fire, and as the draft does not seem to have been affected by the method of firing, we may assume that the average thickness was the same in both the level and bank firing. The reason for the draft not being greater in test No. 1278, where a thick fire was carried at the back end, is that the fire was very thin in front and most of the air supply for the fire came through that portion of the grate.

Conclusions.

26. Of the two methods of firing, the results for the bank firing, as practiced at the Locomotive Test Plant during these tests, show a slightly higher evaporation of water per pound of coal. This is based on the results where a short bank was used. The large bank will be referred to later. The result in favor of the bank firing is due, possibly, more to the skill of the fireman than to the methods used. It would, therefore, seem safe to conclude that the amount of coal used with the low bank fire and with the level fire are the same.

27. If, however, the method of firing as practiced by fireman B1 in test No. 1278 is followed, the results are much less satisfactory than with the level fire. As the bank firing employed in test No. 1278 was used in the first test with a coal from the Lines West of Pittsburgh, it would appear that the size of the bank and the method of firing with it was the style of the bank fire that had been claimed to be more economical than the level fire. This method of bank firing is undoubtedly proved to be far from economical as compared with level firing, and the fact that fireman B1, who formerly advocated this method of firing, changed to the small form of bank after seeing the results, seems to be good evidence that the large bank, as first tried, was in his estimation not to be compared in economy with level firing.

28. It should be emphasized particularly that in speaking of bank firing as a method, the size of the bank which is to be employed must be clearly understood. The general statement that bank firing and level firing can be placed on a par, so far as economy in fuel is concerned, is misleading, unless a description of the bank method of firing is given.

29. The idea of the larger bank seems to be that it forms some protection for the fireman against the heat radiated through the firedoor and permits the firing to be done largely at the back end of the firebox, the coal or partly consumed coal working its way forward. It is this method of bank firing which has been shown to be uneconomical.

31. The method of bank firing with the low bank does not require all the coal to be fired at the back end, but requires firing in much the same way as with the level fire. The temperature near the firedoor from this form of bank has been shown to be from 10 to 23 degrees Fahrenheit less than with the level fire.

32. These trials were made on a single locomotive, one having a wide grate and a comparatively shallow firebox or a firebox in which the firedoor and lower tubes are, comparatively, near the grate. With a very deep and narrow firebox the conclusions probably do not apply, neither do they apply to all coals. It is assumed that they do apply to the great majority of locomotives on our own lines.

33. Unless the bank is high it does not protect the fireman from the heat of the fire to any great extent, and when it is high enough for this purpose, or when it extends above the top of the firedoor, very poor results are obtained from the boiler. With the bank extending above the door opening the firing must of necessity be performed in a haphazard manner, as the surface cannot be seen.

RECOMMENDATIONS.

34. We recommend that the instructions to firemen to fire by the level fire method be continued in force (Par. 11 and 28, and Par. 5 Circular 81A, Bulletin 16).

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
Genl. Supt. Motive Power.

TEST DEPARTMENT,
ALTOONA, PENNA.
November 15, 1912.

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

TEST NOS., 1275 to 1293

SUBJECT: Bank Versus Level Firing

ALTOONA, PA., 9-5-1908

No.	Item	Value
	DRIVING WHEELS	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	ENGINE TRUCK WHEELS	
14	Number	2
15	Diameter, inches	30
	TRAILING WHEELS	
16	Diameter, inches	-
	WHEEL BASE, FEET	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	21667
21	" 1st Drivers	45667
22	" 2d "	42583
23	" 3d "	47500
24	" 4th "	40850
25	" 5th "	-
26	" Trailers	-
27	Total	198267
28	" on Drivers	176600
	CYLINDERS	
	Diam. and Stroke, H P	22 x 28
	" " " L. P	-
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.5
41	" " Crank "	10.7
42	" Left, Head "	12.2
43	" " Crank "	10.8
44	L. P. Right, Head "	-
45	" " Crank "	-
46	" Left, Head "	-
47	" " Crank "	-
	RECEIVER, CUBIC FEET	
48	Volume Right Side	-
49	" Left "	-
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	30
51	" " Width	2
58	L. P. " Length	-
59	" " Width	-
66	H. P. Exhaust, Length	No Port
67	" " Width	" "
70	L. P. " Length	-
71	" " Width	-

No.	Item	Value
	PISTON RODS, DIAMETER INCHES	
74	High Pressure	4
76	Low "	-
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	-
80	Low "	-
	VALVES	
82	Type	Piston
83	Design	Amer.Bal.Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walschaerts
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	6.25
88	Low " "	-
	STEAM LAP OF VALVE	
90	High Pressure, inches	.91
94	Low " "	-
	EXHAUST LAP OF VALVE	
98	High Pressure, inches	.06
102	Low " "	-
	BOILER	
113	Type	Belpaire, wide firebox
114	Outside Diam. 1st Ring	71.16
	TUBES	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.6875
118	Length Between Tube Sheets, inches	164.28
119	Total Fire Area, sq. ft.	6.23
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	-
128	Outside Diam. " inches	-
128	Length of " "	-
	FIREBOX, INSIDE, INCHES	
132	Length	118.32
133	Width	65.04
137	Air Inlets to Ashpan, sq. ft.	7.56
	GRATES	
144	Type	Rocking Finger
145	Grate Area, sq. ft.	48.66
146	Area of Dead Grates	0

No.	Item	Value
	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2673.68
155	" " " Fire "	2339.23
156	" " Firebox, " "	166.06
157	" " Superh'r, " "	-
*158	Total, Based on " "	2505.29
159	" " " " " of Firebox and Water Side of Tubes	2839.74
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	349.7
161	Steam " " "	83.1
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.63
167	Area, sq. inches	24.89
	REVERSE LEVER	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	-
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	51.49
172	Fire Area Thru Tubes (119) to Grate Area (145)	.13
173	Firebox Heating Surface (156) to Grate Area (145)	3.41
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.09

*USED IN CALCULATIONS

Table 3.
DIMENSIONS OF CLASS H6b LOCOMOTIVE 2860 USED IN BANK FIRE TEST.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8b
NUMBER 2860

FUEL: West Eureka and Pittsburgh Coal

SUBJECT: Bank versus Level Firing

ALTOONA, PA., 8-24-1908

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Method of Firing	Pressure in Boiler, Lbs. per Sq. inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1275	80-40-F	2.5	13.36	Full		Level	201.6	3.5	0.1	13743	70
1276	80-40-F	2.5	13.36	"		"	197.4	3.5	0.1	13743	108
1277	80-40-F	2.5	13.36	"		Bank	202.0	3.9	0.1	13743	126
1284	80-40-F	1.25	13.30	Full		Level	203.0	3.5	0.1	12364	58
1285	80-40-F	2.50	13.31	"		"	202.3	3.6	0.1	12364	33
1286	80-40-F	2.50	13.31	"		Bank	203.3	3.6	0.1	12364	31
1287	80-40-F	2.50	13.31	"		"	202.9	3.6	0.1	12364	23
1288	80-40-F	2.50	13.31	"		Level	201.0	3.5	0.1	12364	18
1289	100-45-F	2.00	16.64	"		"	200.3	5.1	0.2	12364	44

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1275	3135	64.43	23938	28449	11.36	9.07	824.6	68.74			
1276	3259	66.98	22865	27162	10.84	8.33	787.3	58.54			
1277	3070	63.09	23354	27743	11.07	9.04	804.2	63.33			
1284	3024	62.15	23306	27749	11.08	9.18	804.3	71.71			
1285	3140	64.53	22879	27265	10.88	8.68	790.3	67.80			
1286	3207	65.91	23309	27787	11.09	8.66	805.4	67.65			
1287	2928	60.18	23223	27670	11.04	9.45	802.0	73.81			
1288	2966	60.96	22828	27202	10.86	9.17	788.5	71.63			
1289	4531	93.12	30667	36546	14.59	8.07	1059.3	63.04			

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
1275	23648					22279	794.0	4.9	29.8		4.7	
1276	22579					21521	767.0	4.3	29.4		4.4	
1277	23017					22310	795.1	3.9	29.0		4.8	
1284	22955					22536	802.2	3.8	28.6		5.5	
1285	22575					22170	790.1	4.0	28.6		5.2	
1286	22994					22522	802.7	4.0	28.7		5.2	
1287	22920					22192	790.9	3.7	26.0		5.6	
1288	22543					22276	793.9	3.7	28.4		5.5	
1289	30291					23343	1039.9	4.4	29.1		4.7	

Table 4.
RESULTS OF BANK AND LEVEL FIRE TESTS.

M. P. 394 A—Sixth Sheet
8 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860

FUEL: Pittsburgh Coal Co.

SUBJECT: Bank Versus Level Firing

ALTOONA, PA., 8-24-1908

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	Method of Firing	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1290	100-45-F	2.00	16.64	Full		Level	198.4	5.3	0.2	12364	46
1291	100-45-F	2.00	16.64	"		Bank	200.5	5.6	0.1	12364	35
1292	100-45-F	2.00	16.64	"		"	198.7	5.4	0.2	12364	37
1293	100-45-F	2.00	16.64	"		Level	197.3	5.4	0.2	12364	45
1278	100-45-F	2.0	16.71	"		Bank	193.5	5.8	0.1	12447	94
1279	100-45-F	2.0	16.71	"		Level	197.7	5.7	0.1	12447	102
1280	100-45-F	2.0	16.71	"		Bank	201.8	5.8	0.2	12447	54
1281	100-45-F	2.0	16.71	"		Level	202.0	5.7	0.1	12447	20
1282	100-45-F	2.0	16.71	"		Bank	200.5	5.7	0.2	12281	48
1283	100-45-F	2.0	16.71	"		Level	199.7	5.5	0.2	12281	56

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
1290	4491	92.30	30668	36541	14.59	8.14	1059.2	63.58			
1291	4118	84.61	30478	36351	14.51	8.83	1053.7	68.97			
1292	4694	96.47	30807	36722	14.66	7.82	1064.4	61.09			
1293	4199	86.29	30056	35807	14.29	8.53	1037.9	66.63			
1278	5169	106.23	29955	35597	14.21	6.89	1031.8	53.46			
1279	5074	104.28	31375	37306	14.89	7.35	1081.4	57.03			
1280	4624	95.03	31738	37753	15.07	8.16	1094.3	63.32			
1281	4408	90.59	31747	37764	15.07	8.57	1094.6	66.50			
1282	4669	95.95	31343	37287	14.88	7.99	1080.8	62.83			
1283	4825	99.12	31297	37213	14.85	7.72	1078.6	60.71			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)
	214	379	380	381		265	383	384	385	398	399
1290	30297					23255	1036.0	4.3	29.3		4.8
1291	30100					23028	1025.9	4.0	29.3		5.1
1292	30434					23093	1028.8	4.6	29.6		4.5
1293	29691					22897	1020.1	4.1	29.1		5.0
1278	29593					22191	988.6	5.2	29.9		3.9
1279	30995					22558	1005.0	5.1	30.8		4.1
1280	31554					23431	1045.9	4.4	30.0		4.6
1281	31545					23185	1032.9	4.3	30.4		4.7
1282	30952					23220	1034.5	4.5	29.9		4.6
1283	30862					23085	1028.4	4.7	30.0		4.4

Table 5.
RESULTS OF BANK AND LEVEL FIRE TESTS

GRAPHICAL LOG OF TEST.

The following diagrams show the boiler pressure, speed, drawbar pull and weight of coal and water for each ten minute interval of the test. A diagram is drawn for each test and is on file with the Test Plant records. A few representative diagrams are shown here.

M. P. Experimental D-1

12 9 1911
8 x 10½

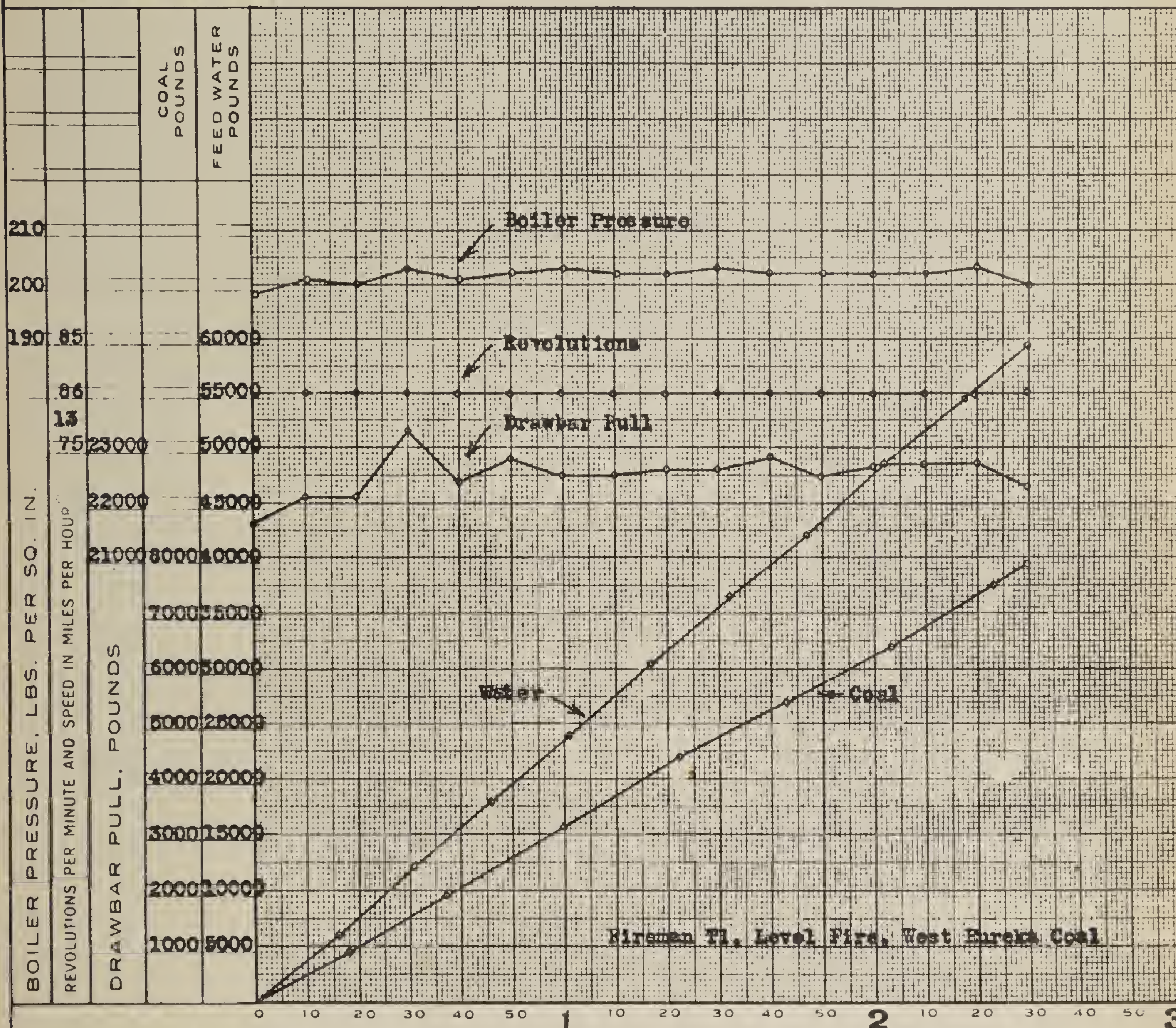
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-465 | TEST DEPARTMENT | Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus level Fire. | ALTOONA, PA., 8-17-1908



LENGTH OF TEST— MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.36	80	40	Full	7.57

TEST NO. 1275

SHEET NO. P-465

M. P. Experimental D-1

12 9 1911
8 x 10½

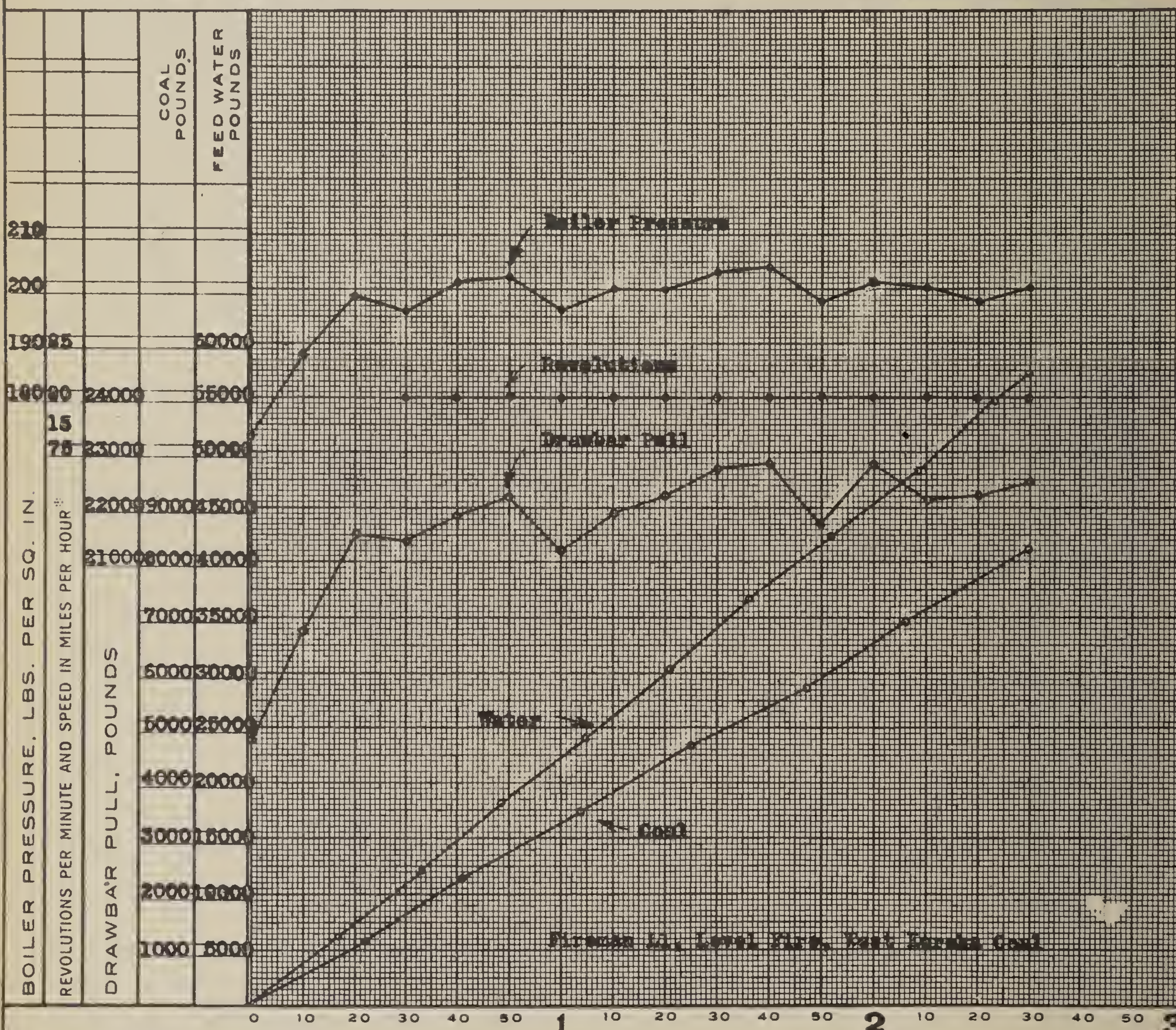
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-466 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank Versus Level Fire ALTOONA, PA., 8-18-1908



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.36	80	40	Full	6.96

TEST NO. 1276

SHEET NO. B-466

M. P. Experimental D-1

12 9 1911
8 x 1914

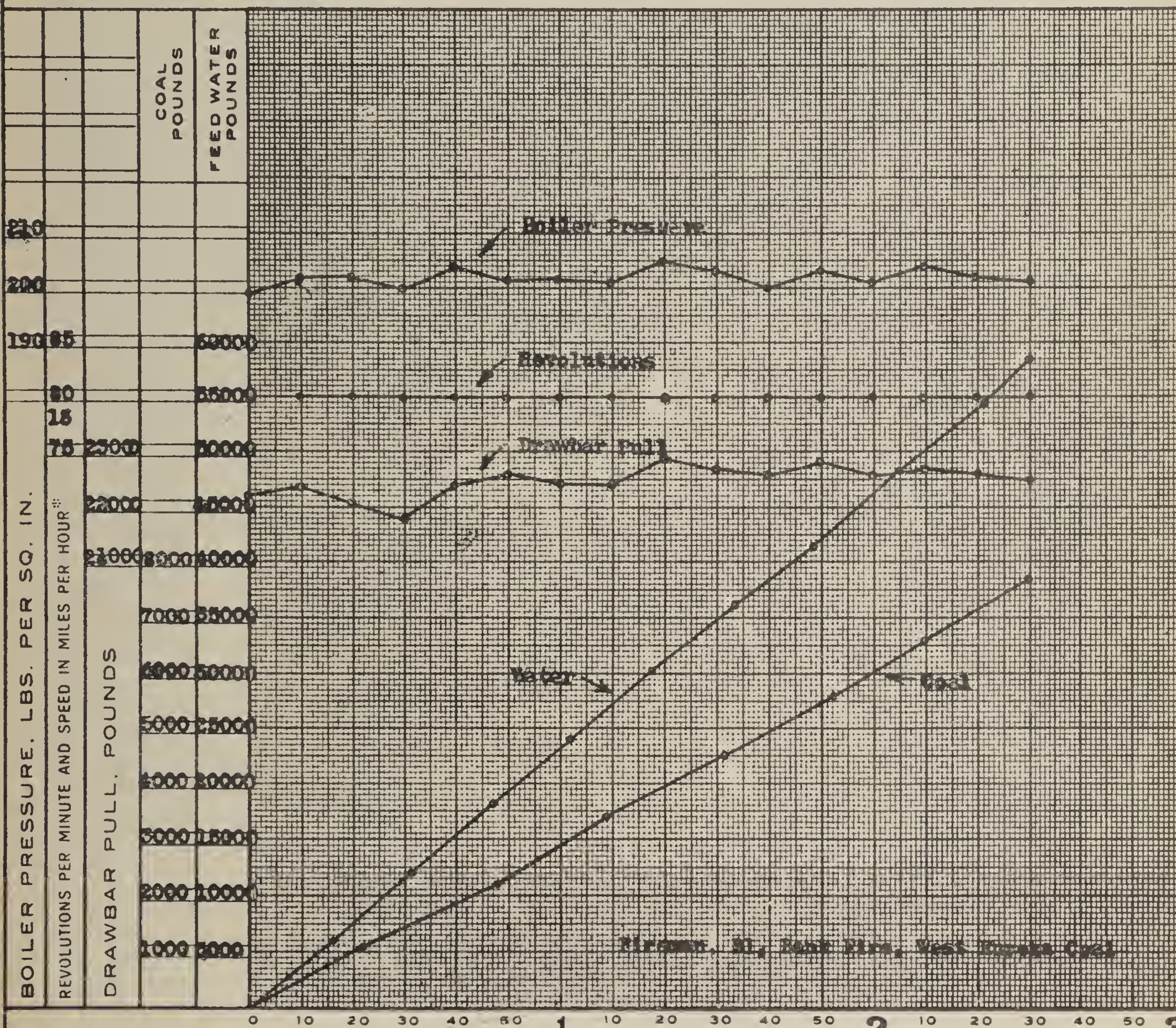
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-467 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 8-18-1908



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.36	80	40	Full	7.15

TEST NO. 1277

SHEET NO. P-467

M. P. Experimental D-1

12 9 1911
8 x 10½

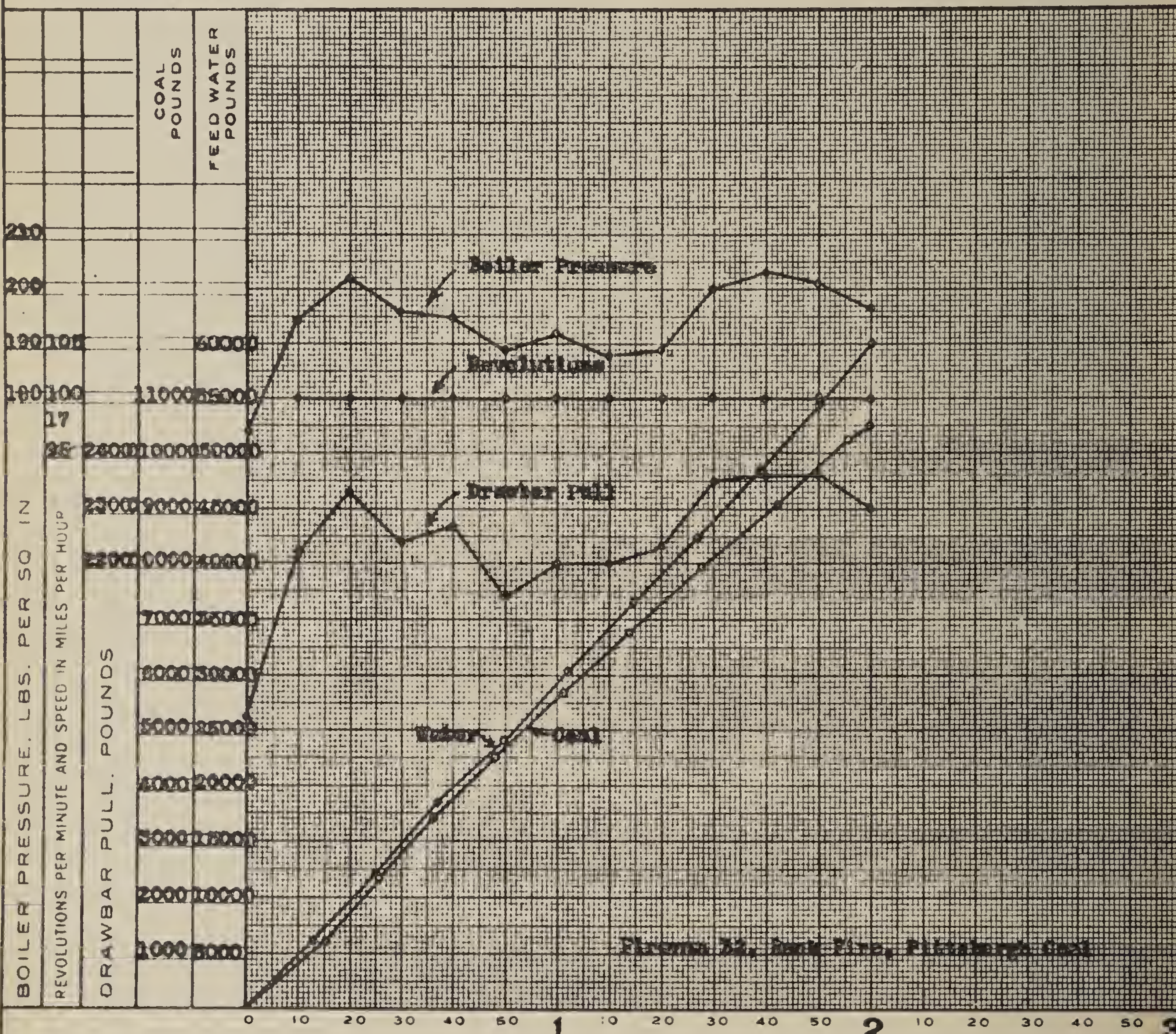
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-468 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 8-19-1908



UPPER FIGURES R. P. M
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	5.69

TEST NO. 1278

SHEET NO. P-468

M. P. Experimental D-1

12 9 1911
8 x 10½

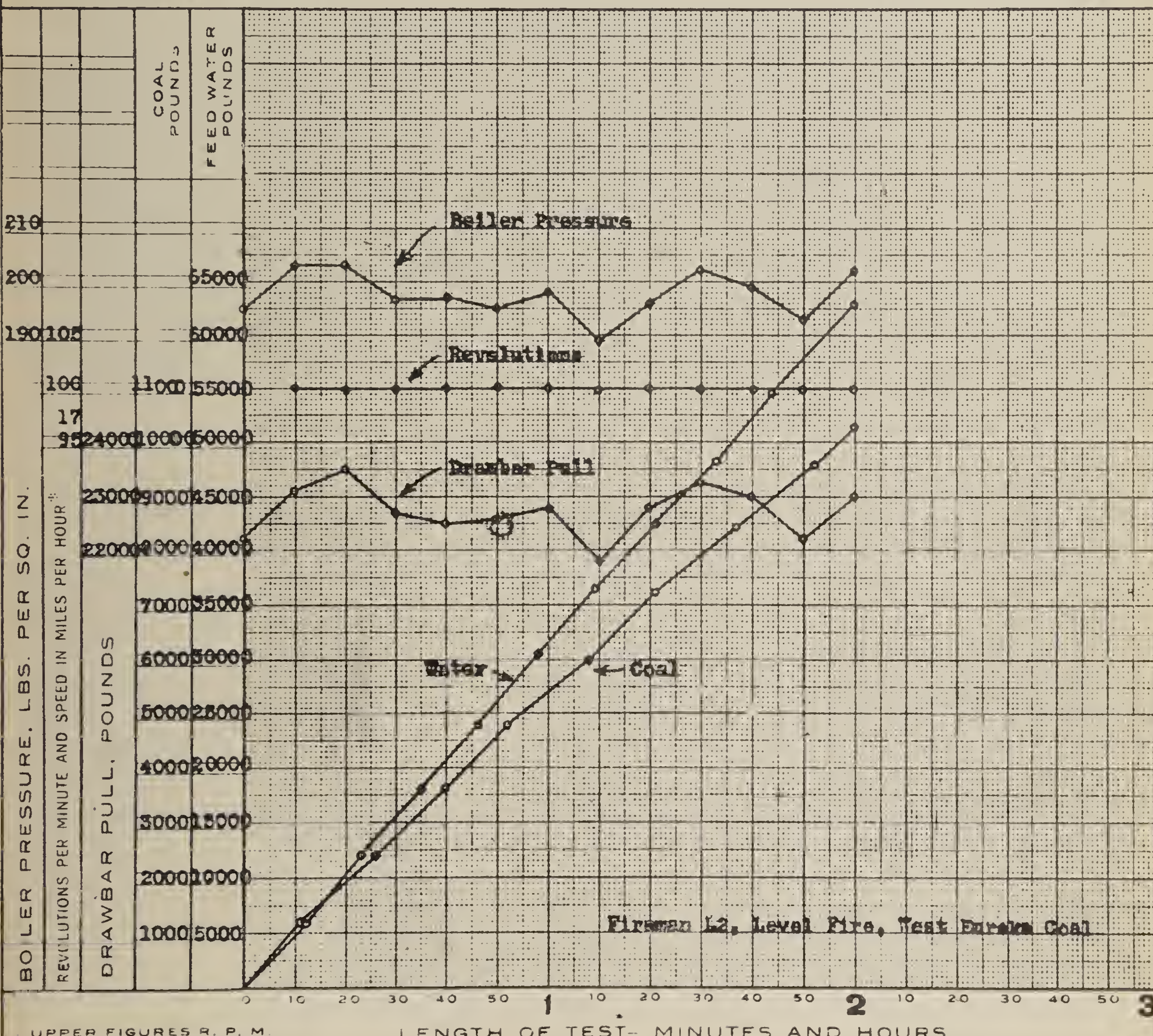
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-469 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire. ALTOONA, PA., 8-20-1908



UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent. H. P. Cylinder	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	6.07

TEST NO. 1279

SHEET NO. P-469

M. P. Experimental D-1 12 9 1911 8 x 10½

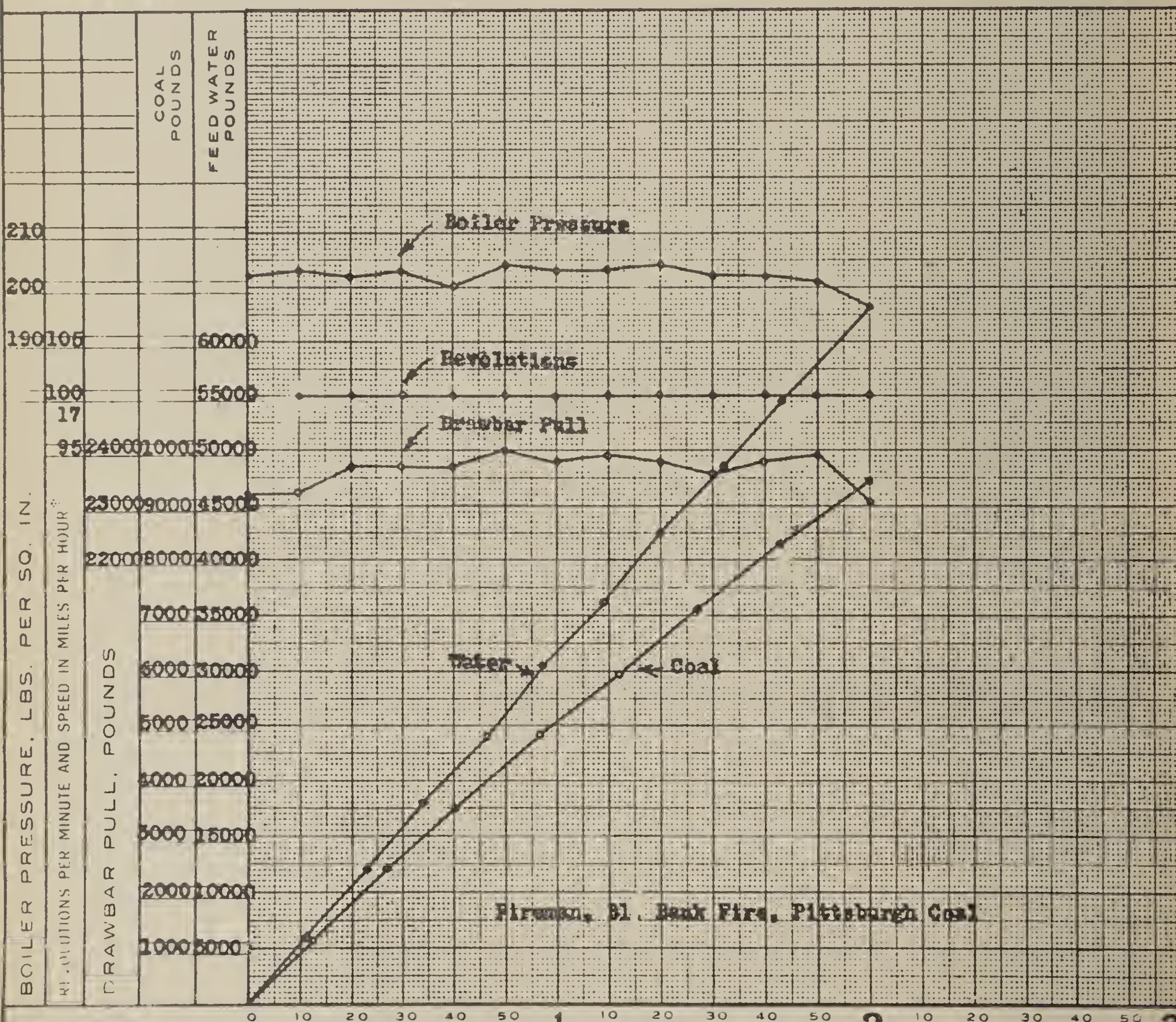
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-470 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 8-20-1908



UPPER FIGURES R. P. M
LOWER FIGURES APPROX
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	6.74

TEST NO. 1280

SHEET NO. P-470

M. P. Experimental D-1

12 9 1911
8 x 10½

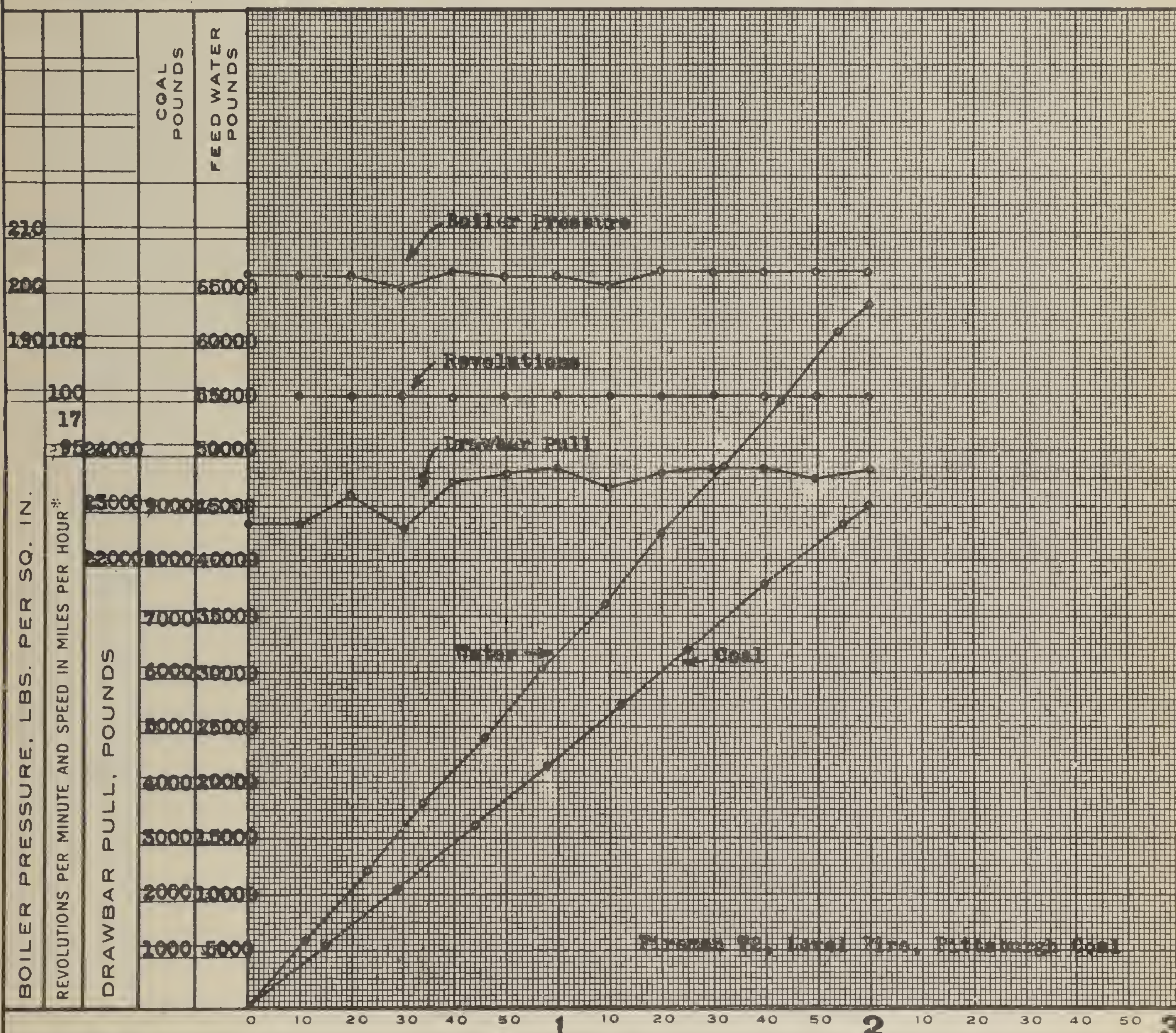
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-471 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank Versus Level Fire ALTOONA, PA., 8-21-1908



LENGTH OF TEST—MINUTES AND HOURS

*UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	7.15

TEST NO. 1281

SHEET NO. P-471

M. P. Experimental D-1

13 9 1911
8 x 10½

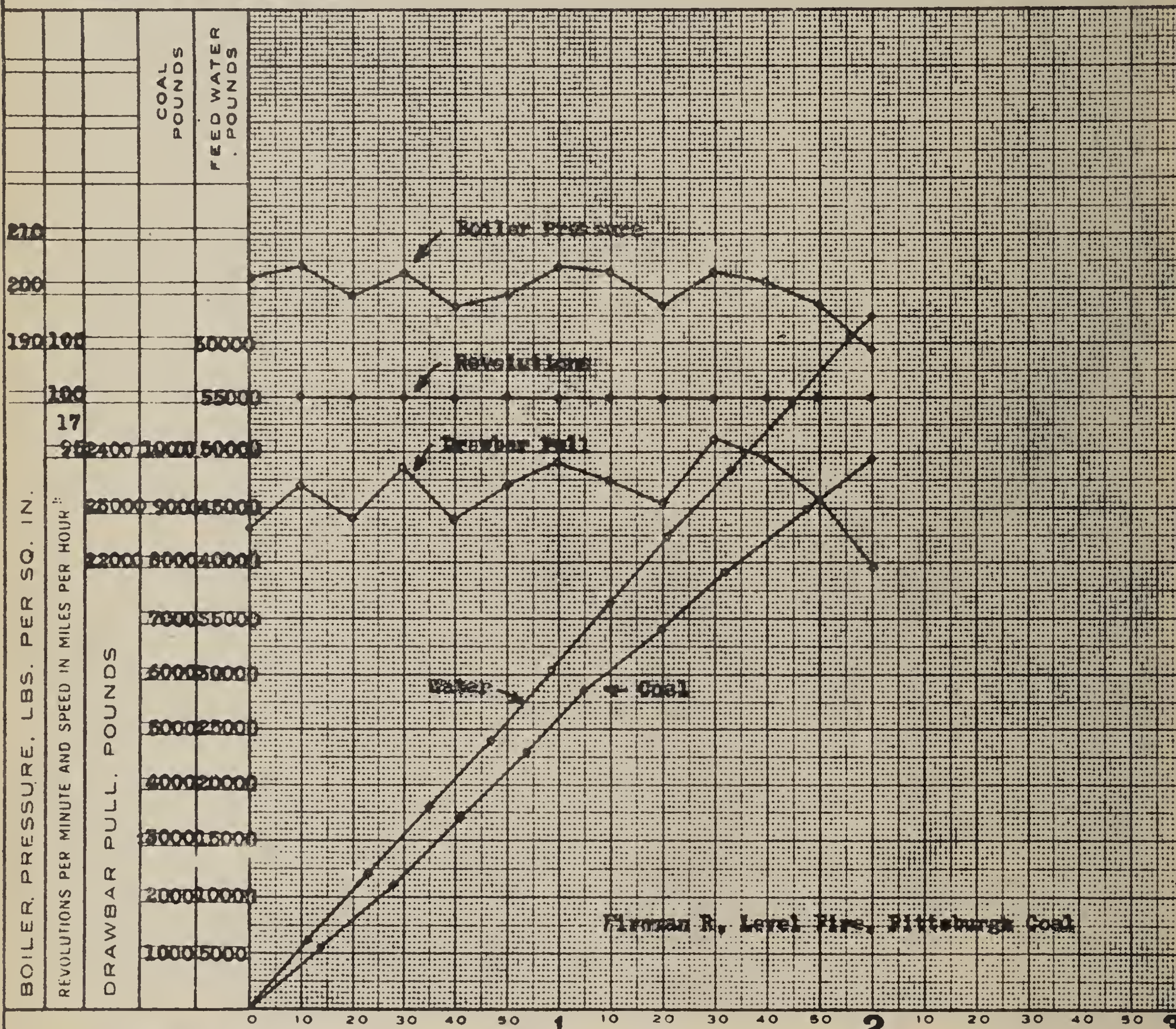
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-472 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire. ALTOONA, PA., 8-22-1908



UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.71	100	45	Full	6.33

TEST NO. 1283

SHEET NO. P-472

M. P. Experimental D-1

12 9 1911
8 x 10½

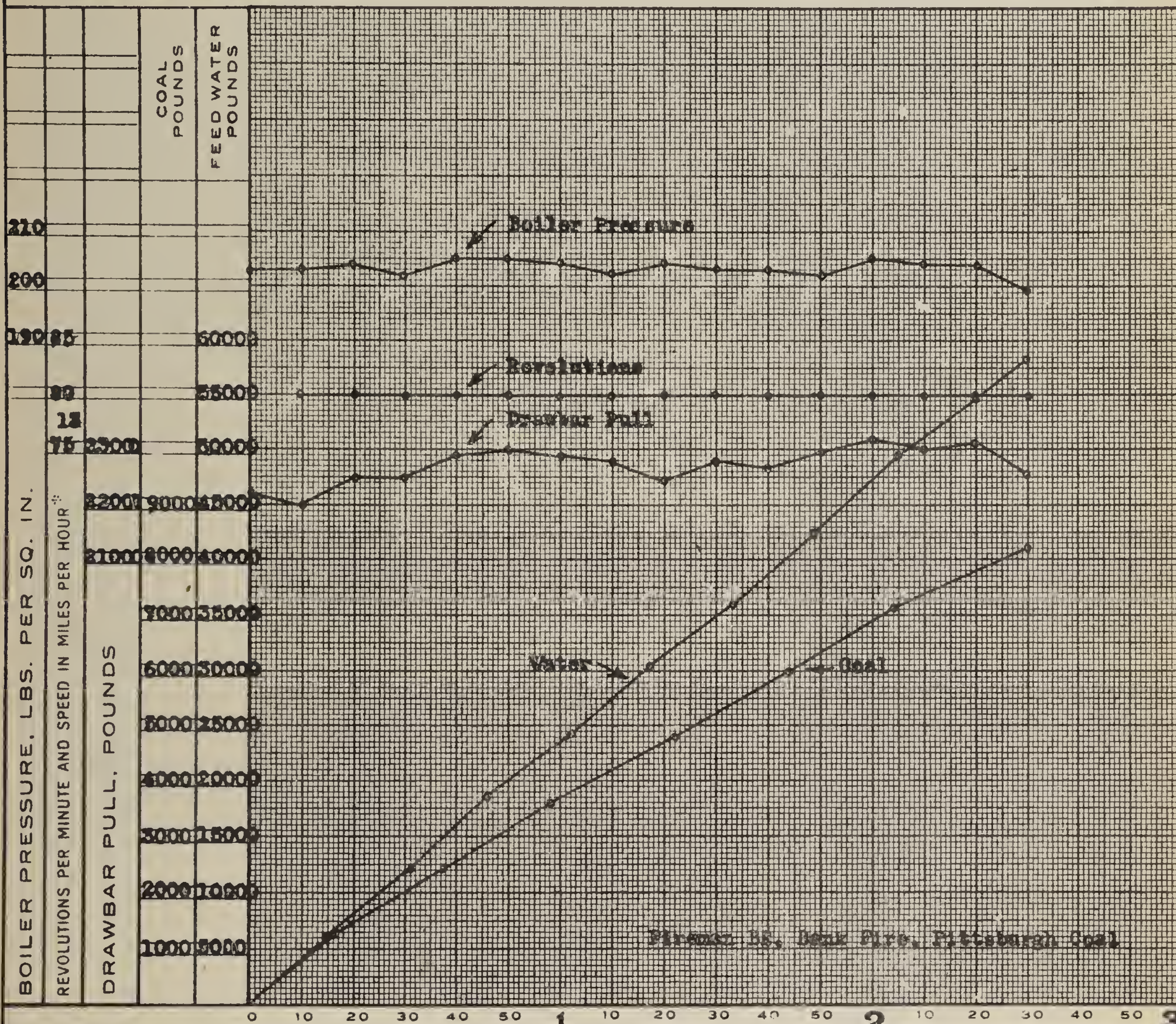
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-473 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire. ALTOONA, PA., 9-1-1908



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M.
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
13.31	80	40	Full	7.11

TEST NO. 1286

SHEET NO. P-473

M. P. Experimental D-1

12 9 1911
8 x 10½

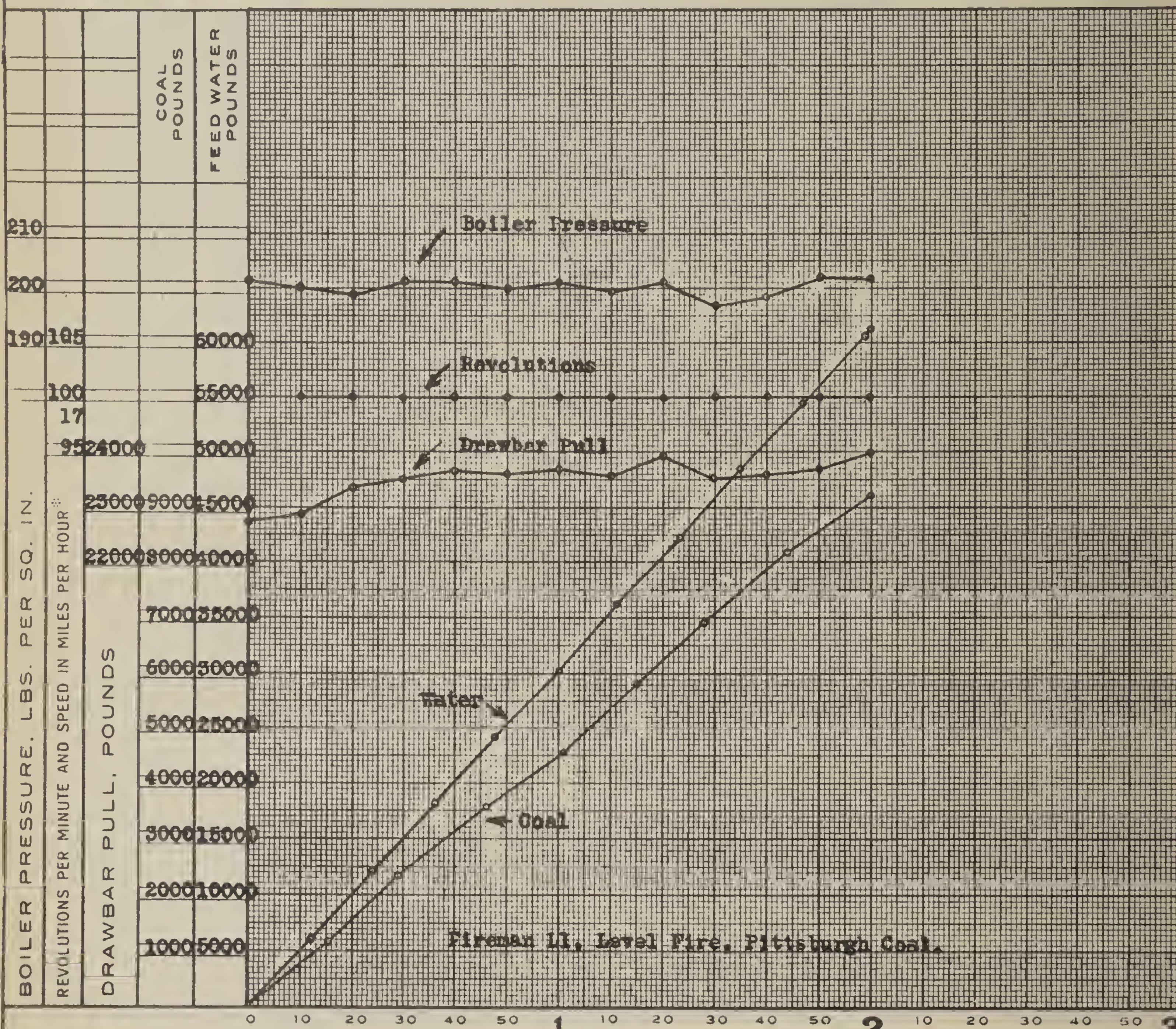
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-474 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 9-3-1908



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	6.63

TEST NO. 1289

SHEET NO. P-474

M. P. Experimental D-1

12 9 1911
8 x 10½

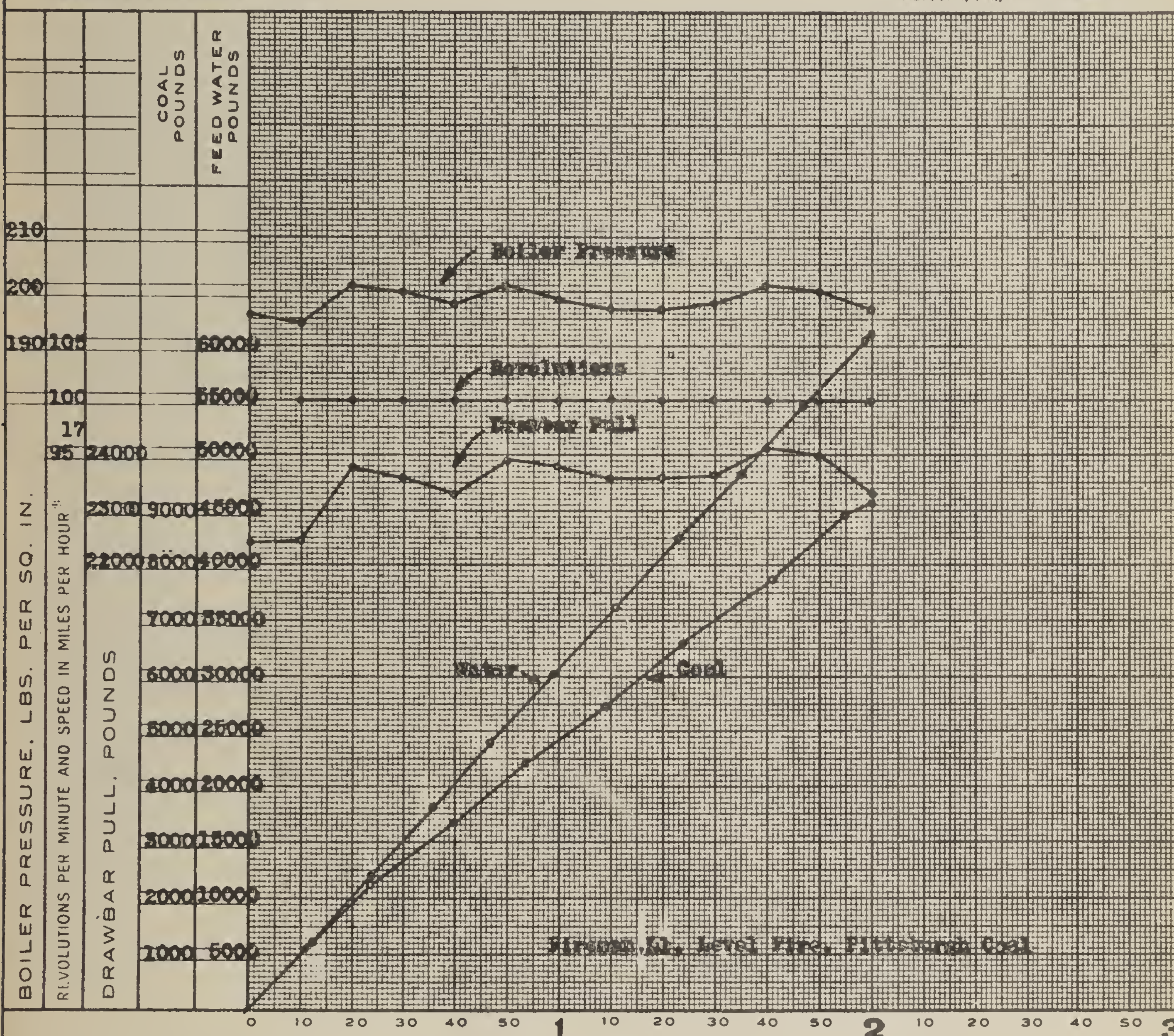
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-475 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 9-3-1908



∴ UPPER FIGURES R. P. M
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	6.69

TEST NO. 1298

SHEET NO. P-475

M. P. Experimental D-1 — 13 9 1911 8 x 10½

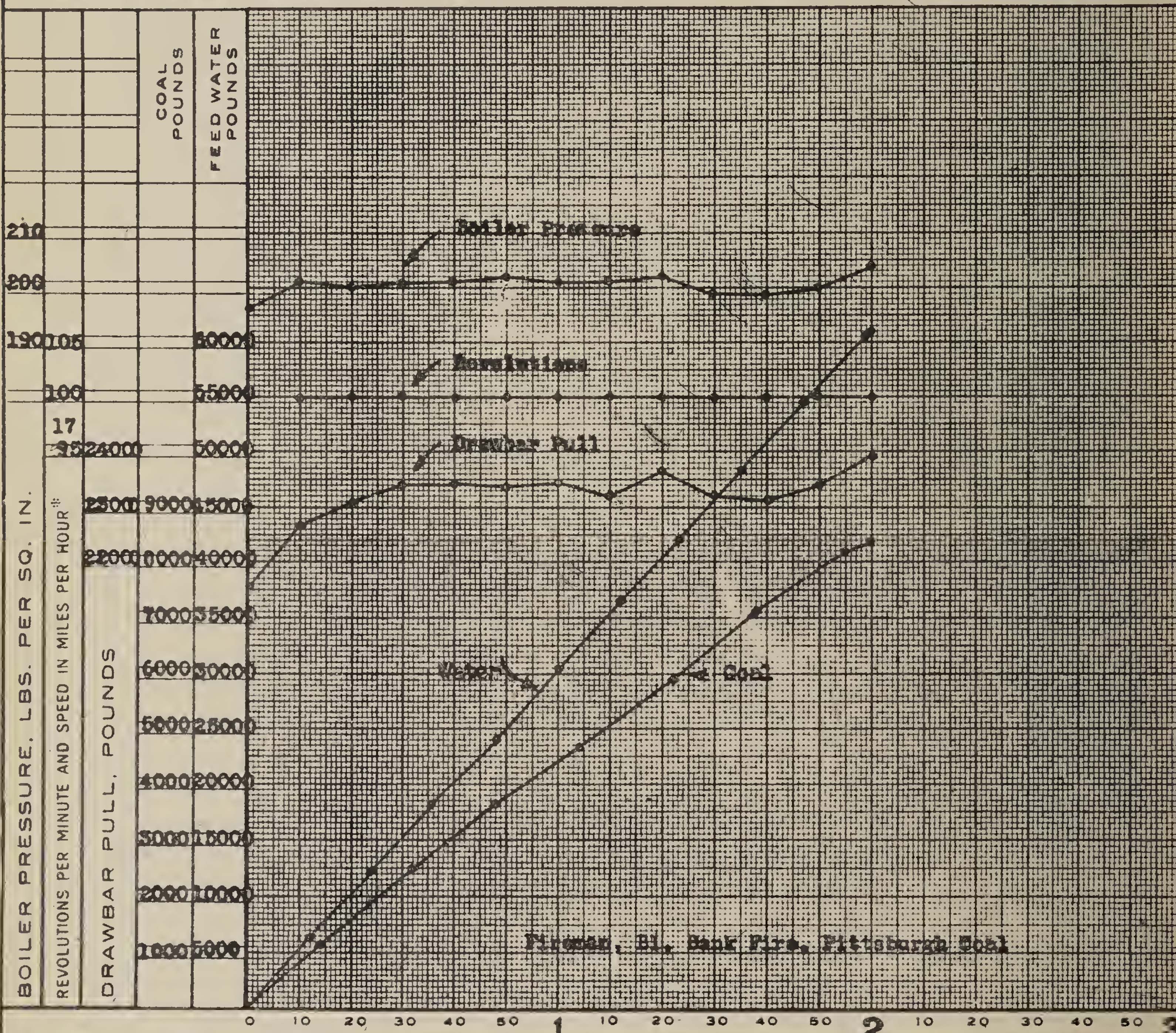
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-476 — TEST DEPARTMENT — Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire — ALTOONA, PA., 9-4-1908



LENGTH OF TEST—MINUTES AND HOURS

* UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	7.24

TEST NO. 1291

SHEET NO. P-476

M. P. Experimental D-1 — 12 9 1911 — 8 x 10½

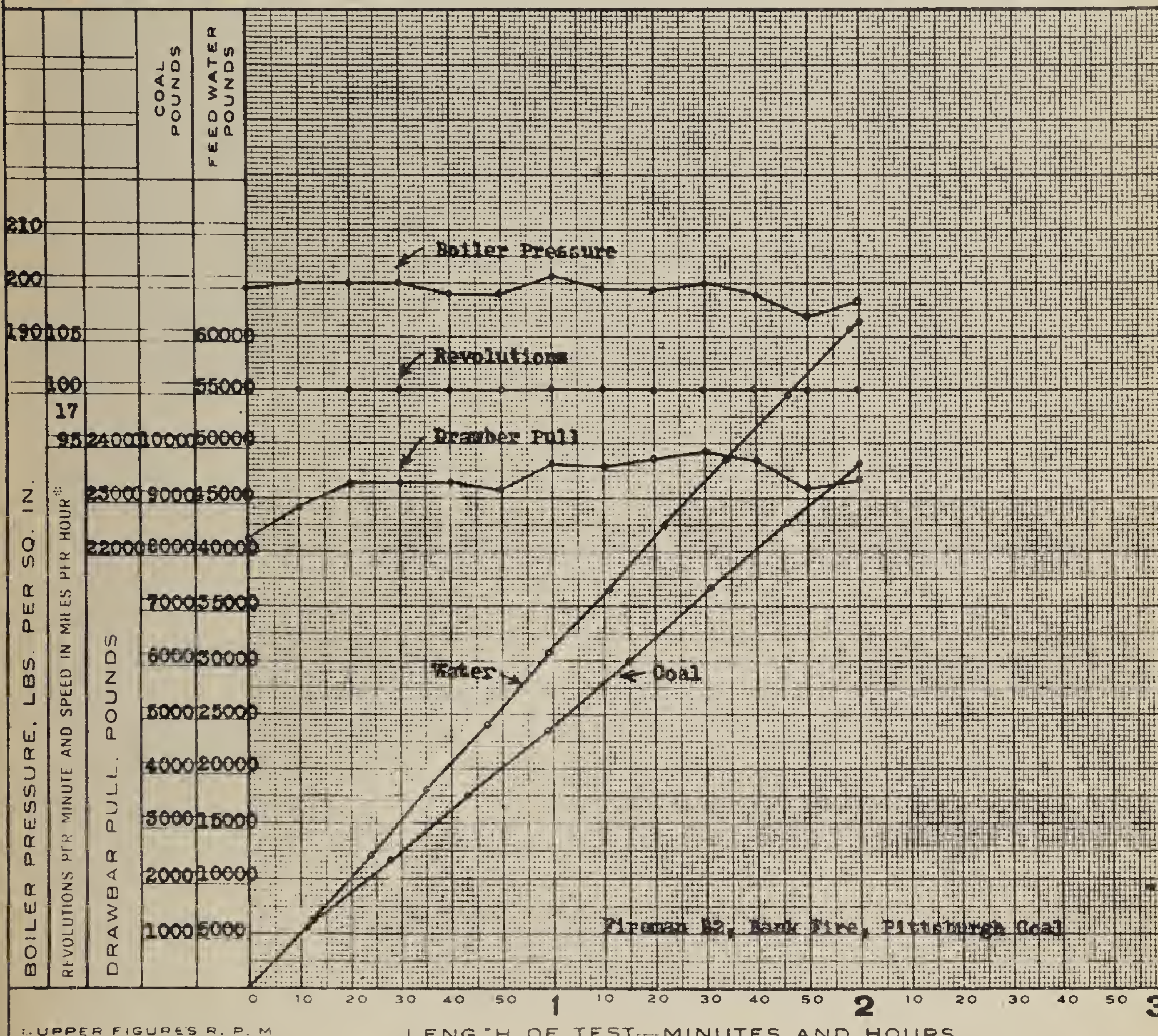
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-477 — TEST DEPARTMENT — Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank Versus Level Fire — ALTOONA, PA., 9-4-1908



*UPPER FIGURES R. P. M.
LOWER FIGURES APPROX. SPEED IN MILES PER HOUR

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	6.42

TEST NO. 1292

SHEET NO. P-477

M. P. Experimental D-1

12 9 1911
8 x 10½

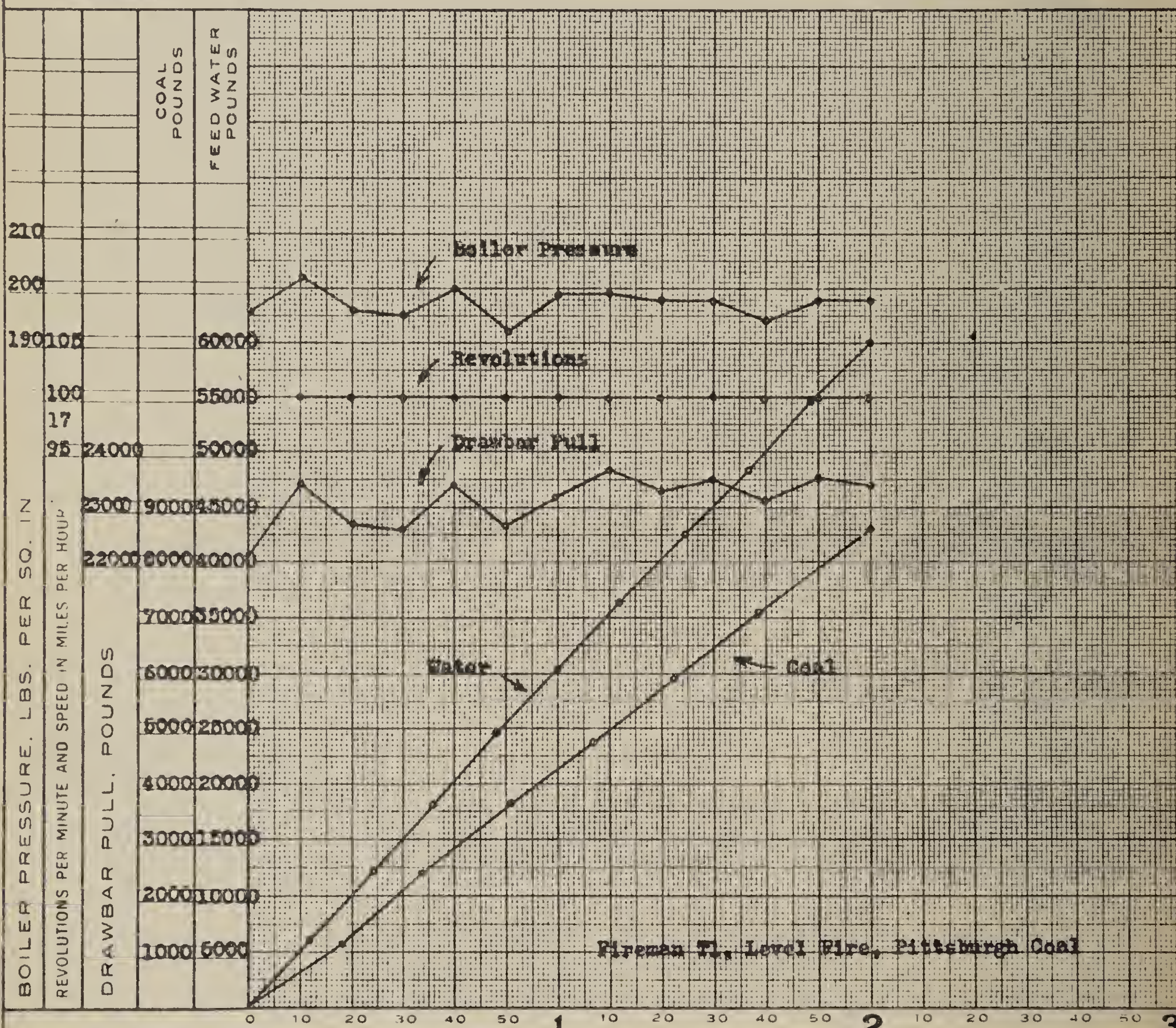
PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

SHEET NO. P-478 TEST DEPARTMENT Bulletin NO. 12

GRAPHICAL LOG OF LOCOMOTIVE TEST

Bank versus Level Fire ALTOONA, PA., 9-5-1908



UPPER FIGURES R. P. M
LOWER FIGURES APPROX.
SPEED IN MILES PER HOUR

LENGTH OF TEST—MINUTES AND HOURS

LOCOMOTIVE
TYPE 2-8-0
CLASS H6b
NUMBER 2860

Speed in Miles per Hour	Revolutions per Minute	Cut-off Per Cent., H. P. Cylinders	Throttle Opening Full or Partial	Evaporation Pounds of Water per Pound of Coal
16.64	100	45	Full	7.01

TEST NO. 1293

SHEET NO. P-478

16

PENNSYLVANIA RAILROAD COMPANY

TEST DEPARTMENT

Locomotive Testing Plant

Fuel Economy Tests

Circular No. 81

LOCOMOTIVE TESTING PLANT.

LOCOMOTIVE TESTS

IN CONNECTION WITH CIRCULAR No. 81, "INSTRUCTIONS TO ENGINEMEN AND FIREMEN FOR THE ECONOMICAL USE OF FUEL."

CONCLUSIONS.

The tests at the Locomotive Testing Plant cover but a few of the items of Circular No. 81, and the items investigated show the following:

First.—A saving of fuel will result if the instructions are carefully followed.

Second.—On the class "H6b" locomotive, having a grate area of about 50 square feet, there must be burned upwards of 20,000 pounds of coal before the ashes that accumulate on the grate will have a marked effect upon the fire.

Third.—There are some coals which form a large amount of clinker in the fire, and to these the above conclusions do not apply; there seems to be few of such coals.

Fourth.—A clean fire is at all times the most economical.

Fifth.—Regular firing of coal, in small quantities, according to the demand for steam, gives better results than irregular firing where large quantities of coal are fired with long intervals between firing. The loss in evaporation with irregular firing was about 9 per cent. for the single trial that was made.

Sixth.—Under ordinary conditions, the fire door should be kept on latch, but when the locomotive is working easily it is best to close the door, except for a short time just after firing. When the evaporation was about eleven pounds per square foot of heating surface, with this locomotive, the saving in coal was about 12.5 per cent. by keeping the door on latch.

Seventh.—Irregular boiler feeding not only wastes steam at the safety valves at low water levels, but on one test shows a loss in evaporation of about 15 per cent. over regular feeding. The loss or waste of coal is 450 pounds per hour, or 12.5 per cent., and for a one-hundred-mile run the coal fired would be 23,238 pounds with regular boiler feeding and 26,648 pounds with irregular feeding, a difference of 3140 pounds of coal.

Eighth.—It requires a steam leak of considerable size in the cylinders to affect, appreciably, the economy of the engines of the locomotive, though a leak of any size will reduce the power developed.

Ninth.—A leak at the cylinder cocks is not so wasteful as one at the piston rod packing or at the steam chest.

Tenth.—The loss in drawbar pull, due to failure in maintaining a good boiler pressure, can best be illustrated by the following comparison taken from one of the tests: At 200 pounds boiler pressure the drawbar pull was 21,800 pounds and at 191 pounds pressure it was 20,400 pounds, a loss of 1400 pounds with a decrease of only 9 pounds boiler pressure, or a loss of 6 per cent. in drawbar pull.

LOCOMOTIVE TESTS

IN CONNECTION WITH CIRCULAR No. 81, "INSTRUCTIONS TO ENGINEMEN AND FIREMEN FOR THE ECONOMICAL USE OF COAL."

Fuel Economy.

1. It is estimated that fully one-fourth of all the coal mined is used in locomotives, and on the Pennsylvania Railroad the cost of fuel is one of the largest single items of expenditure in conducting transportation.

2. In an endeavor to lessen some of the wastes of fuel which are known to occur, a circular of instruction was issued to enginemen and firemen (see copy attached) June 1, 1908.

Meeting of Road Foremen.

3. On September 9, 1908, all road foremen and assistants were called to Altoona for a discussion of this Circular 81, and their suggestions were asked as to what tests could be undertaken on the Locomotive Testing Plant to try out some or all of the means of coal saving outlined in the circular.

4. The result of this conference was, that it would be possible to make the following tests:

(*a*) For item No. 3, steam leaks, a small leak could be made in each cylinder and the loss of steam determined.

(*b*) For item No. 4, admission of air through the grates, a test to be made without shaking the grates and without previous cleaning of the fire.

3-17-10
8x14

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

CIRCULAR 81-A

Instructions to Enginemen and Firemen for the Economical Use of Coal

(SUPERSEDING INSTRUCTIONS No. 81, DATED JUNE 1, 1908.)

1. Enginemen and firemen must work together so as to save coal and reduce smoke.

2. Enginemen and firemen when taking charge of a locomotive must see that the fire, grates and ash pan are in good condition so as to prevent engine failures on the road.

3. Enginemen must include in their reports on M. P. Form 62 all defects causing leaks of steam or water in any part of the locomotive, as the repairs of these defects will avoid loss of coal.

4. The burning of bituminous coal in a locomotive requires air, which must be admitted through the grates and through the fire door.

Smoke means waste of coal and must be avoided.

Large quantities of coal placed in the firebox at one time cool down the fire, cause smoke and waste coal; small quantities at regular intervals will keep the fire bright, prevent smoke and take less coal to keep up steam pressure.

Lumps of coal should be broken in pieces not larger than three inches.

5. A bright and level fire over the whole grate must be carried whenever possible. When a sloping fire is used, no more coal should be banked at the door than is necessary.

6. To prevent smoke and to save coal, the fire door must be placed on or against the latch after firing coal or using the scraper, slash bar or hook, and when on sidings, in yards, at terminals or before starting.

7. Before the throttle is closed, the blower must be used and the door placed on the latch. Firemen must stop firing long enough before steam is shut off to prevent smoke and waste of coal.

8. Dead spots in the fire must be avoided when running with throttle closed, as this frequently causes flues to leak.

9. The grates must be shaken as often as is necessary to clear the fire of ash and clinker in order to admit sufficient air, and in such a manner as to avoid the loss of good fire. Care should be taken to place the grates level after each operation.

10. The waste of steam at safety valves must be avoided. One shovel full of coal is required to make the steam that escapes from a safety valve in one minute.

11. The sprinkling hose attached to the injector must be used frequently to keep down dust on the foot plate and in the cab and to wet coal in the tender. However, too much water on the coal should be avoided, as to some extent this practice is the cause of flues stopping up.

12. Coal must not be allowed to collect or remain on the foot plate, but should be swept into the coal space of tender, and not out on the tracks.

13. Engines must not be brought into terminals with a dead fire, which will cause flues to leak; nor with too heavy a fire, which will cause waste of coal.

14. When banking or cleaning fires, the blower should be used as lightly as possible. After the fire has been cleaned of ash and clinker, the clean fire must be placed at the front end of the grates and maintained in good condition.

15. When cleaning fires or with a banked fire, excessive use of the injectors must be avoided, as this will result in injury to the flues.

16. After taking coal at coaling stations, the fireman must do the necessary trimming of coal pile, to insure the prevention of coal falling off of tenders while in transit, which is both wasteful and dangerous to passing trains, trackmen, etc.

17. Coal can be saved by the proper use of the injector in pumping locomotive regularly, and by taking advantage of every opportunity to fill boiler when not working locomotive to full capacity; also by using the injector to avoid the safety valves blowing off.

18. Coal will be saved by always working the locomotive (except when starting) with a full throttle when the cut-off is one-quarter of the stroke or greater; but if one-quarter cut-off with full throttle gives more power or speed than is needed, the reverse lever should be left at one-quarter cut-off and the throttle partially closed as needed.

A. W. GIBBS,
General Superintendent Motive Power.

APPROVED:

W. HEYWARD MYERS,
General Manager.

MARCH 17, 1910.

(*c*) For the third paragraph of item No. 4, relating to irregular firing, a test to be made by firing from 6 to 8 shovelfuls of coal with long intervals between firing.

(*d*) For item No. 6, relating to the fire door, a test to be made with the fire door kept closed, except when actually firing, and the same run repeated, but with the fire door not closed but left against the latch.

(*e*) For item No. 17, relating to the handling of the injector, a test to be made with the injector used intermittently, with large variations in water level.

5. In addition to the foregoing, it was brought out at the meeting that road foremen would like to know the effect of running the locomotive in a manner similar to road conditions; that is, the locomotive to be run for a time at a certain speed and cut-off, and then to have the speed and cut-off increased as would occur in road service in making a given schedule or in overcoming grades.

6. It was also desired to have made: A test of lump coal as compared with "run-of-mine" coal, and a test to be made with the water in the boiler at a very high level, and another reversing the conditions or having the water level as low as possible.

7. These tests were undertaken in order that there might be established some data in regard to the extent of the saving that would result from an application of the instructions in Circular 81. They were not undertaken in an effort to disprove the correctness of the statements made. There is a very general agreement that the instructions, if followed, will result in economy of fuel, but their force would be greater if there could be some results of trials, with measured quantities of fuel, for reference. It was with the object of providing such data that these tests have been made.

The Tests.

8. A series of tests have now been completed covering the points above noted. They have been made as opportunity offered while other tests were in progress, so that they have not been made in consecutive order, in all cases; but where comparisons of tests have been made, it is thought that such comparisons are entirely fair.

9. All of the tests were made with the same locomotive, a class "H6b" Consolidation. This locomotive is shown in outline on the diagram No. 1201, and the principal dimensions are shown on table No. 1203.

LOCOMOTIVE.
TYPE 2-8-0
CLASS H6B
NUMBER 2860

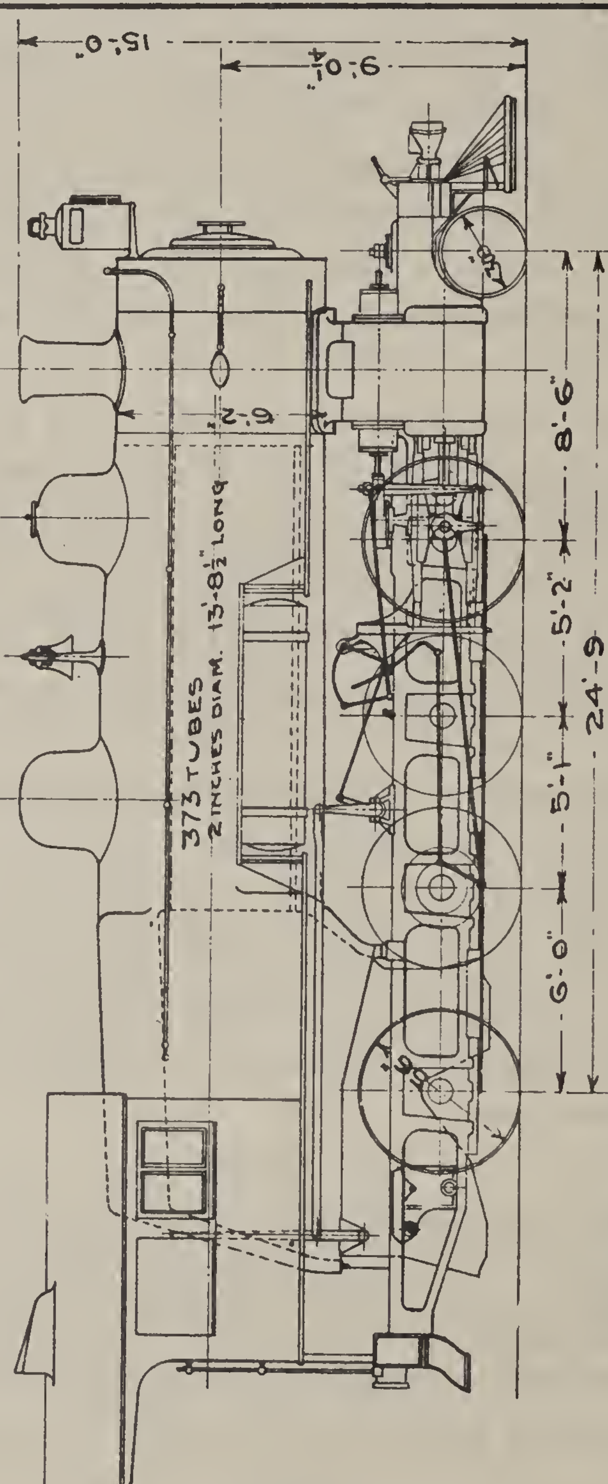
PENNSYLVANIA RAILROAD COMPANY

TEST DEPARTMENT

LOCOMOTIVE TESTING PLANT

SUBJECT LOCOMOTIVE DIAGRAM H6B

ALTOONA, PA. 8-10-08



CYLINDERS 22 x 28

HEATING SURFACE OF TUBES (FIRESIDE) SQ.FT.	2339.23
FIREBOX " " "	166.06
TOTAL " " "	2505.29
GRATE AREA " "	48.66
WORKING BOILER PRESSURE, LBS. PER SQ.IN.	205
WEIGHT OF LOCOMOTIVE IN WORKING ORDER	198267 LBS.

1201

M. P. 894A
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

TEST NOS.,

SUBJECT: CIRCULAR No. 81 TESTS — ALTOONA, PA., 8-10-08

No.	Item	Value
	DRIVING WHEELS	
1	Number of Pairs	4
2	Approx. Diameter, inches	56
	ENGINE TRUCK WHEELS	
14	Number	2
15	Diameter, inches	30
	TRAILING WHEELS	
16	Diameter, inches	—
	WHEEL BASE, FEET	
17	Driving Wheel Base	16.25
18	Total Wheel Base	24.84
19	Gage of Wheels	4.75
	WEIGHT OF ENGINE WITH WATER AT 2D. GAGE COCK AND NORMAL FIRE, POUNDS	
20	On Truck	21667
21	" 1st Drivers	45667
22	" 2d "	42583
23	" 3d "	47500
24	" 4th "	40850
25	" 5th "	—
26	" Trailers	—
27	Total	198267
28	" on Drivers	176600
	CYLINDERS	
	Diam. and Stroke, H. P.	22x28
	" " " L. P.	—
	CLEARANCE IN PER CENT. OF PISTON DISPLACEMENT	
40	H. P. Right, Head End	12.5
41	" " Crank "	10.7
42	" Left, Head "	12.2
43	" " Crank "	10.8
44	L. P. Right, Head "	—
45	" " Crank "	—
46	" Left, Head "	—
47	" " Crank "	—
	RECEIVER, CUBIC FEET	
48	Volume Right Side	—
49	" Left "	—
	STEAM PORTS, INCHES	
50	H. P. Admission, Length	30
51	" " Width	2
58	L. P. " Length	—
59	" " Width	—
66	H. P. Exhaust, Length	No Port
67	" " Width	"
70	L. P. " Length	—
71	" " Width	—

No.	Item	Value
	PISTON RODS, DIAMETER INCHES	
74	High Pressure	4
76	Low "	—
	TAIL RODS, DIAMETER, INCHES	
78	High Pressure	—
80	Low "	—
	VALVES	
82	Type	Piston
83	Design	Amer. Bal. Valve Co.
84	Per Cent. Balanced	100
85	Type of Valve Motion	Walschaerts
	GREATEST VALVE TRAVEL	
86	High Pressure, inches	6.25
88	Low " "	—
	OUTSIDE LAP OF VALVE	
90	High Pressure, inches	.91
94	Low " "	—
	INSIDE LAP OF VALVE	
98	High Pressure, inches	.06
102	Low " "	—
	BOILER	
113	Type	Belpaire, Wide Firebox
114	Outside Diam. 1st Ring	71.16
	TUBES	
115	Number	373
116	Outside Diam., inches	2
	Pitch "	2.6875
118	Length Between Tube Sheets, inches	164.28
119	Total Fire Area, sq. ft.	6.23
124	Boiler Pressure, pounds	205
	SUPERHEATER	
125	Number of Tubes	—
126	Outside Diam. " inches	—
128	Length of " "	—
	FIREBOX, INSIDE, INCHES	
132	Length	118.32
133	Width	65.04
137	Air Inlets to Ashpan, sq. ft.	7.56
	GRATES	
14[illegible]	Type	Rocking Finger
145	Grate Area, sq. ft.	48.66
146	Area of Dead Grates	0

No.	Item	Value
	HEATING SURFACE, SQUARE FEET	
154	Of the Tubes, Water Side	2673.68
155	" " " Fire "	2339.23
156	" " Firebox, " "	166.06
157	" " Superh'r, " "	—
*158	Total, Based on " "	2505.29
159	" " " " " of Firebox and Water Side of Tubes	2839.74
	BOILER VOLUME WITH WATER SURFACE AT LEVEL OF 2D GAGE COCK	
160	Water Space, cu. ft.	349.7
161	Steam " " "	83.1
	EXHAUST NOZZLE	
162	Double or Single	Single
163	Size, inches	5.63
167	Area, sq. inches	24.89
	REVERSE LEVER	
168	H. P. Notches Forward of Center	22
169	L. P. Notches Forward of Center	—
	RATIOS	
171	Heating Surface (158) to Grate Area (145)	51.49
172	Fire Area Thru Tubes (119) to Grate Area (145)	.13
173	Firebox Heating Surface (156) to Grate Area (145)	3.41
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	14.09

*USED IN CALCULATIONS

1203

Steam Leaks.

Leaks at Cylinder Cocks.

10. Tests have been made to show the amount of steam that may be wasted by leaks about the cylinders of the locomotive.

11. These tests were made in two ways: first, by running the locomotive with the cylinder cocks open, and again by running with a hole in each cylinder head.

12. In the tests with the cylinder cocks open, diaphragms having 5/32″ holes were placed in the openings from each of the four cylinder cocks. In test 1200.37 the cylinder cocks were wide open to the atmosphere, and in 1200.48 they were opened into a 3″ drain pipe which led out of the building.

13. In the tests with the cylinder cocks open, but with the 5/32″ hole for the escape of steam and water, there was less steam used per horsepower hour than when there were no leaks.

14. The average steam per horsepower hour for three tests without leaks was 24.64 pounds, while with the cylinder cocks open the average steam per horsepower hour was 24.00 pounds.

15. Much water was observed at the leaks at the cylinder cocks, and it is possible that the discharge of this water may account for the better cylinder performance. A much larger number of tests would be required to settle this definitely, however.

16. While there would seem to be advantages in providing a small outlet at each cylinder to drain off the moisture that collects, such a drain would be very objectionable, and a better method of securing dry steam in the cylinders would be to use a superheater for the steam supply. The matter has not been investigated sufficiently for any positive statements to be made at this time.

Leaks at Centers of Cylinder Heads.

17. When it was found that the leaks provided at the cylinder cocks were discharging much water and but little steam, it was decided that holes should be made in the cylinders above where the water would collect. These holes were made in the center of each front cylinder head. The holes were ½″ in diameter, and the tests made with them are Nos. 1200.137 to 1200.139.

18. Much more steam was lost in this way than from the cylinder cocks. The leaks were larger than anything that would occur in service. In test 1200.136, without leaks, 18,703 pounds of steam were supplied to the cylinders per hour, or 23.44 pounds

M. P. 394 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL:

SUBJECT: CIRCULAR No. 81 TESTS

ALTOONA, PA., 12-21-08

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	POSITION OF CYLINDER COCKS	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	226	248	238
1200.120	80-30-F	.5	13.19	FULL		CLOSED	202.7				
1200.10	80-40-F	1.0	13.31	"		CLOSED	200.1				
1200.36	80-40-F	.5	13.31	"		CLOSED	200.8				
1200.119	80-30-F	.5	13.19	"		OPEN	204.0	5/32 INCH DIAPHRAGM HOLE.			
1200.9	80-40-F	1.0	13.31	"		OPEN	200.2	"			
1200.43	80-40-F	.5	13.31	"		OPEN	202.4	"			
1200.37	80-40-F	.5	13.31	"		OPEN	201.3	ALL CYL COCKS OPEN			
1200.48	80-40-F	.5	13.31	"		OPEN	203.0	" "	"	" TO DRAIN PIPE.	

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.120			19090								
1200.10			22745								
1200.36			22404								
1200.119			18544								
1200.9			22213								
1200.43			22780								
1200.37			22832								
1200.48			23016								

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)
	214	379	380	381		265	383	384	385	398	399
1200.120	18802	784.2		23.98		18295	652.0				
1200.10	22470	927.5		24.23		21925	781.4				
1200.36	22133	882.4		25.08		21598	769.8				
1200.119	18320	789.5		23.20		18706	666.7				
1200.9	21944	914.6		23.99		21638	771.2				
1200.43	22460	904.9		24.82		22056	786.1				
1200.37	22556	898.8		25.10		21814	777.5				
1200.48	22738	879.0		25.87		21324	760.0				

M. P. 394 A—Sixth Sheet
8 x 10½

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PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL:

SUBJECT: CIRCULAR No. 81 TESTS

ALTOONA, PA., 12-21-08

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	198	199	203	268 to 271		217	222	225	248	238
1200.136	80-30-F	1.0	13.19	FULL		NO LEAK	202.9				
1200.138	80-40-F	1.0	13.19	"		"	202.6				
1200.137	80-30-F	.5	13.19	"		LEAK	199.6	½ INCH HOLE AT CENTER OF CYLINDER HEAD			
1200.139	80-40-F	.5	13.19	"		"	201.3	"	"	" "	"

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	346	347	349	350		220	230
1200.136			19047								
1200.138			23031								
1200.137			19474								
1200.139			23320								

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)
	214	379	380	381		265	383	384	385	398	399
1200.136	18703	797.8		23.44		18486	658.8		28.39		
1200.138	22752	928.5		24.50		22619	806.1		28.22		
1200.137	19237	771.9		24.92		17686	630.3		30.52		
1200.139	23038	916.5		25.14		22077	786.8		29.28		

per horsepower hour. In test No. 1200.137, where with the same running conditions the cylinders were leaking, the steam supplied to the cylinders was 19,237 pounds per hour, or 24.92 pounds per indicated horsepower hour. This is an increase of 524 pounds per hour, or about 3 per cent., which would be equivalent to a coal loss of 65 pounds per hour.

Fire Door on Latch or Partly Open.

19. The usual method of firing is to have the fire door closed at all times except when putting coal on the fire and for a short time after firing to burn off the volatile combustible of the coal.

20. To note the effect of having the fire door on the latch all of the time during a test, a series of seven tests have been made. Four tests were run with the fire door closed, except when firing, and three tests during which the fire door was never entirely closed but was placed against the latch, except when firing.

21. Some of the results of these tests are given in the following table:

Test Number	Test Designation	Boiler Pressure	Draft in Smokebox	Dry Coal per Hour, Pounds	Equivalent Evaporation per Hour	Equivalent Evaporation per Pound Dry Coal	Fire Door Open or Closed
1200.114A	80–30–F	203.1	2.6	2644	23117	8.74	Closed.
1200.114	80–30–F	203.5	2.8	2960	23884	8.07	Open.
1200.23	80–40–F	198.4	3.5	3462	27811	8.03	Closed.
1200.27	80–40–F	201.3	3.5	3212	27052	8.42	Closed.
1200.26	80–40–F	201.9	3.5	3067	28319	9.23	Open.
1200.108	100–45–F	204.5	6.6	4968	37813	7.61	Closed.
1200.108A	100–45–F	204.6	6.0	4968	38278	7.70	Open.

22. The best results in evaporation per pound of coal with the fire door open are found at the medium rates of evaporation, which represent average road conditions. At a speed of 80 R. P. M. and a cut-off of 30 per cent., the results are in favor of the closed door. At this speed and cut-off it is probable that sufficient air can be drawn through the thin fire for these running conditions without the additional air which will come through the fire door.

M. P. 394 A—Stub Sheet
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL: SMITH.
WEST PENN C.M.Co
PRESTON.

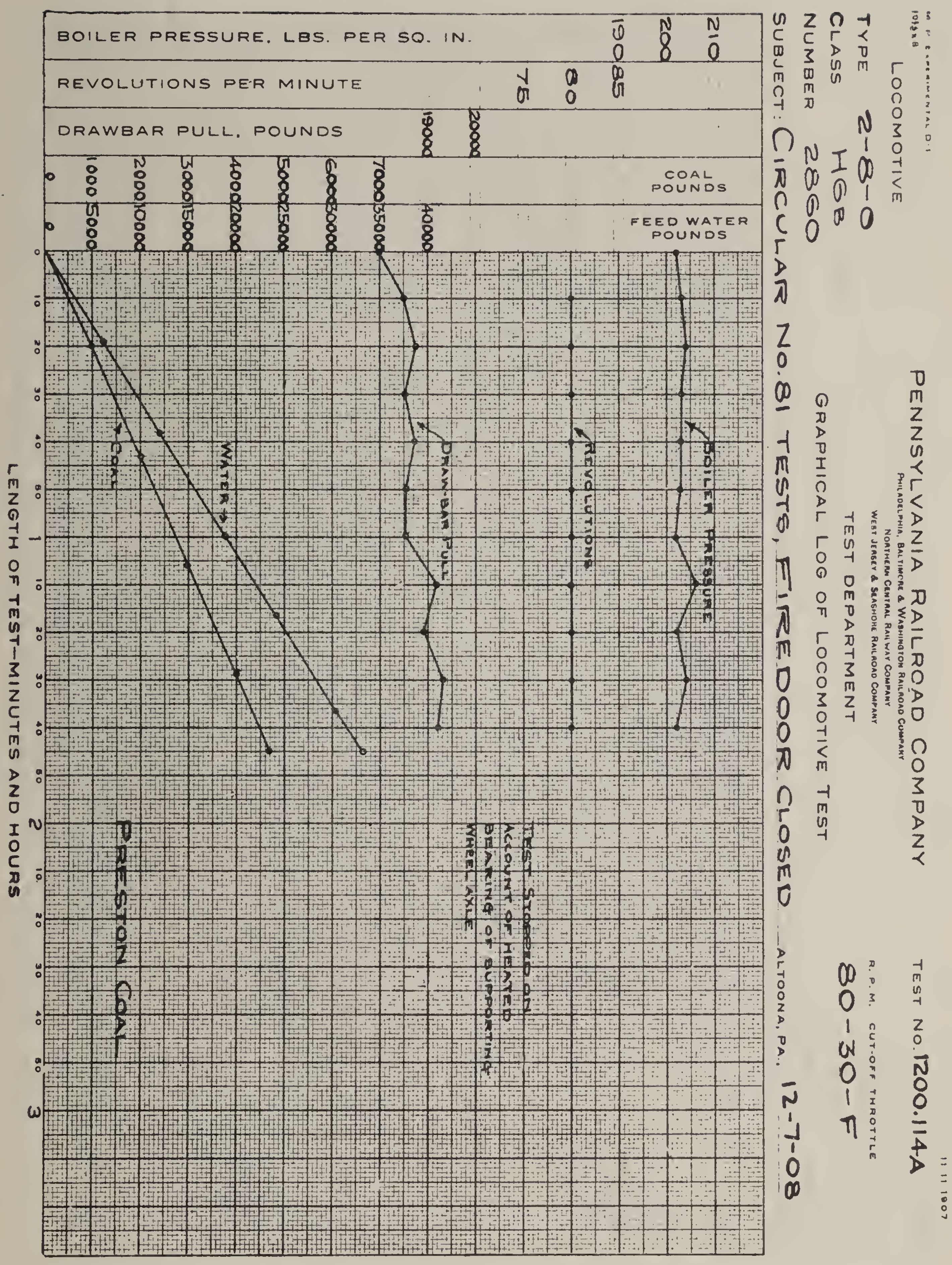
SUBJECT: CIRCULAR No. 81 TESTS.

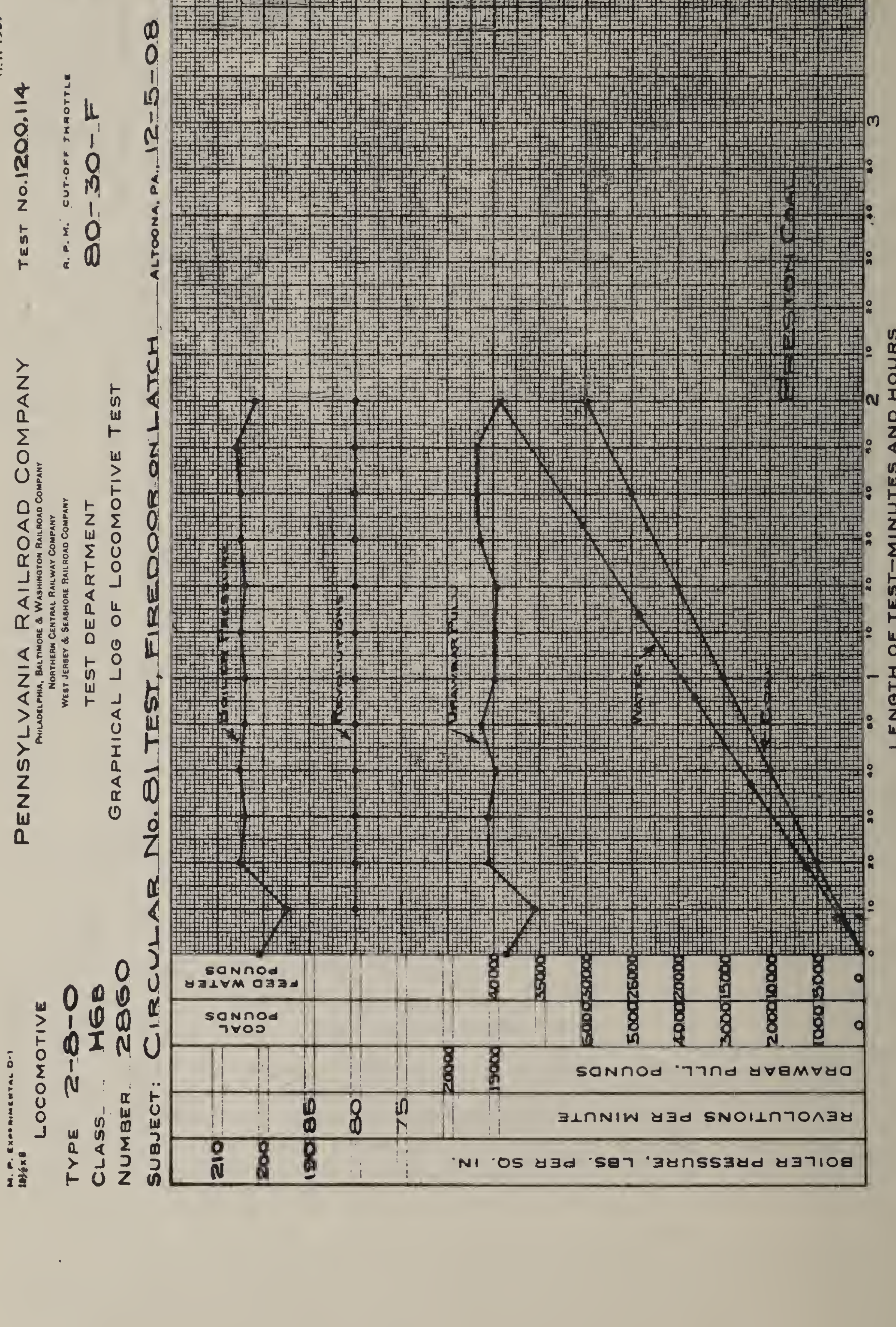
ALTOONA, PA., 12-21-08

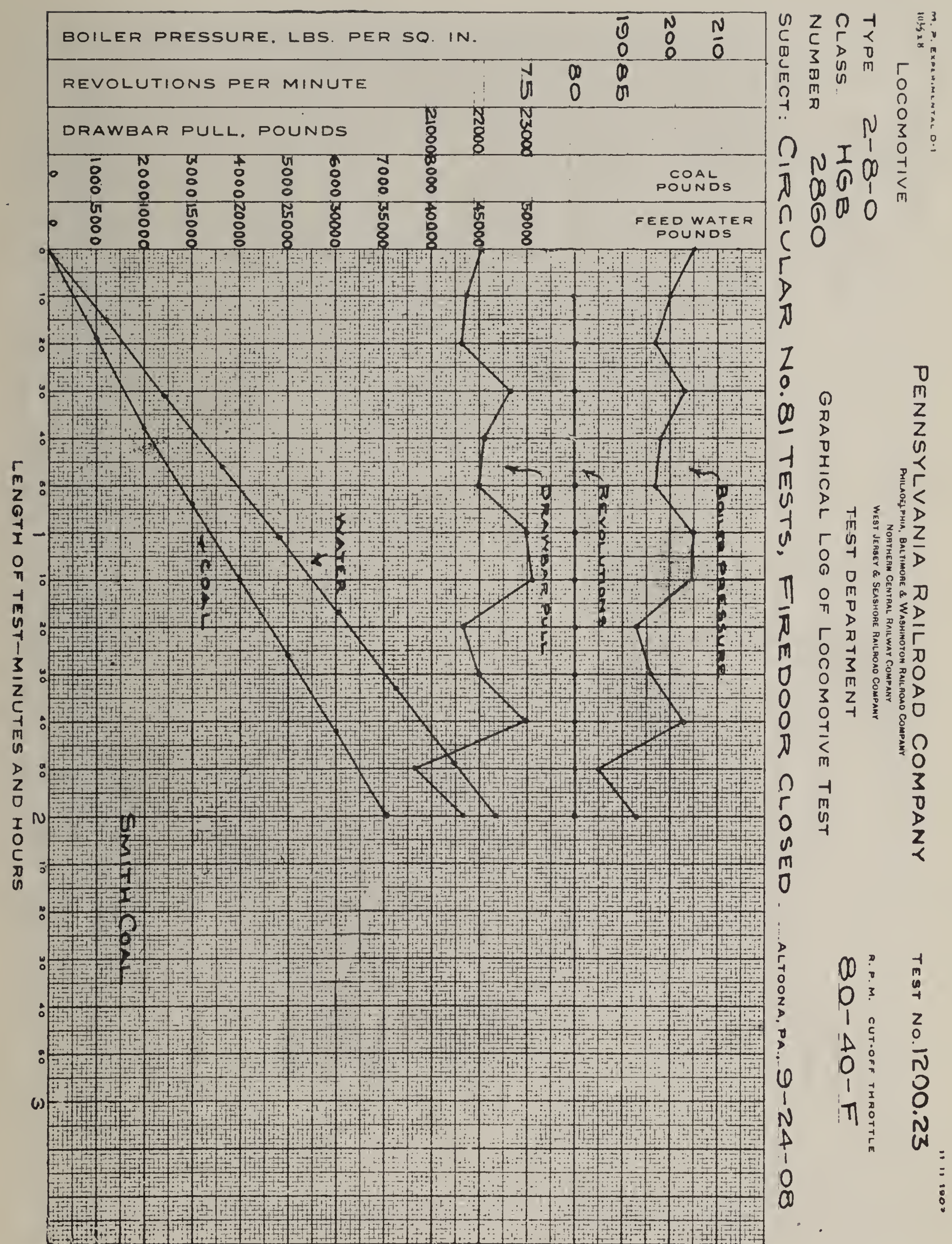
TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	FIRE DOOR	Pressure In Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	B. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.114A	80-30-F	1.75	13.19	FULL		CLOSED	203.1	2.6	.1	12183	30
1200.23	80-40-F	2.00	13.31	"		"	198.4	3.5	.1	13042	37
1200.27	80-40-F	2.00	13.31	"		"	201.3	3.5	.1	13042	46
1200.108	100-45-F	2.00	16.49	"		"	204.5	6.6	.2	13603	30
1200.114	80-30-F	2.00	13.19	"		ON LATCH	203.5	2.8	.2	12183	79
1200.26	80-40-F	2.00	13.31	"		"	201.9	3.5	.1	13042	18
1200.108A	100-45-F	2.00	16.49	"		"	204.6	6.0	.2	13603	41

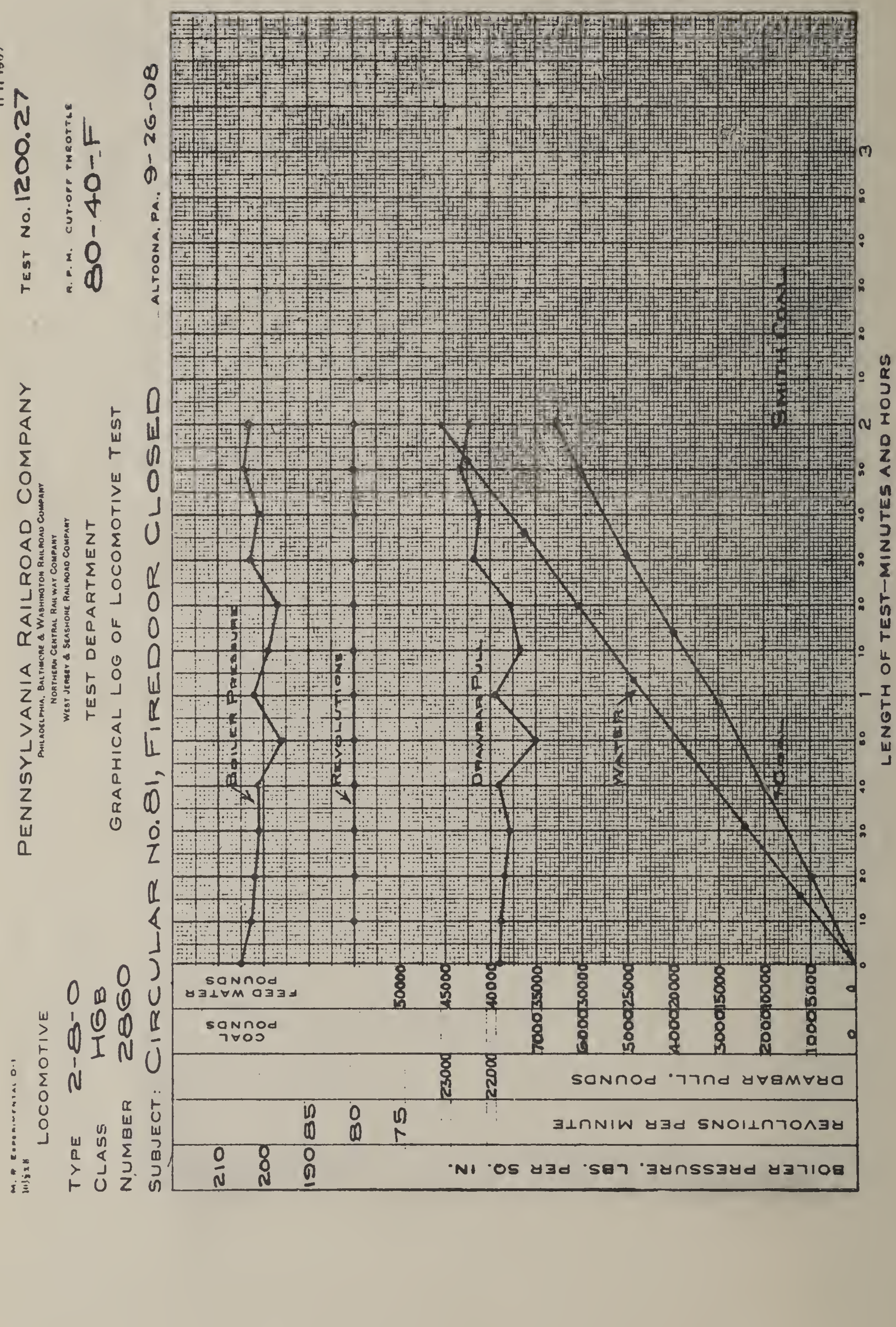
TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	COAL	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.114A	2644	54.34	19035	23117	9.23	8.74	670.1	69.28	PRESTON		
1200.23	3462	71.15	23306	27811	11.10	8.03	806.1	59.46	SMITH		
1200.27	3212	66.01	22672	27052	10.80	8.42	784.3	62.35	SMITH		
1200.108	4968	102.10	31162	37813	15.09	7.61	1096.0	54.03	WEST PENN C.M.Co		
1200.114	2960	60.83	19673	23884	9.53	8.07	692.3	63.97	PRESTON		
1200.26	3067	63.03	23728	28319	11.30	9.23	820.9	68.35	SMITH		
1200.108A	4968	102.10	31494	38278	15.28	7.70	1109.5	54.67	WEST PENN C.M.Co		

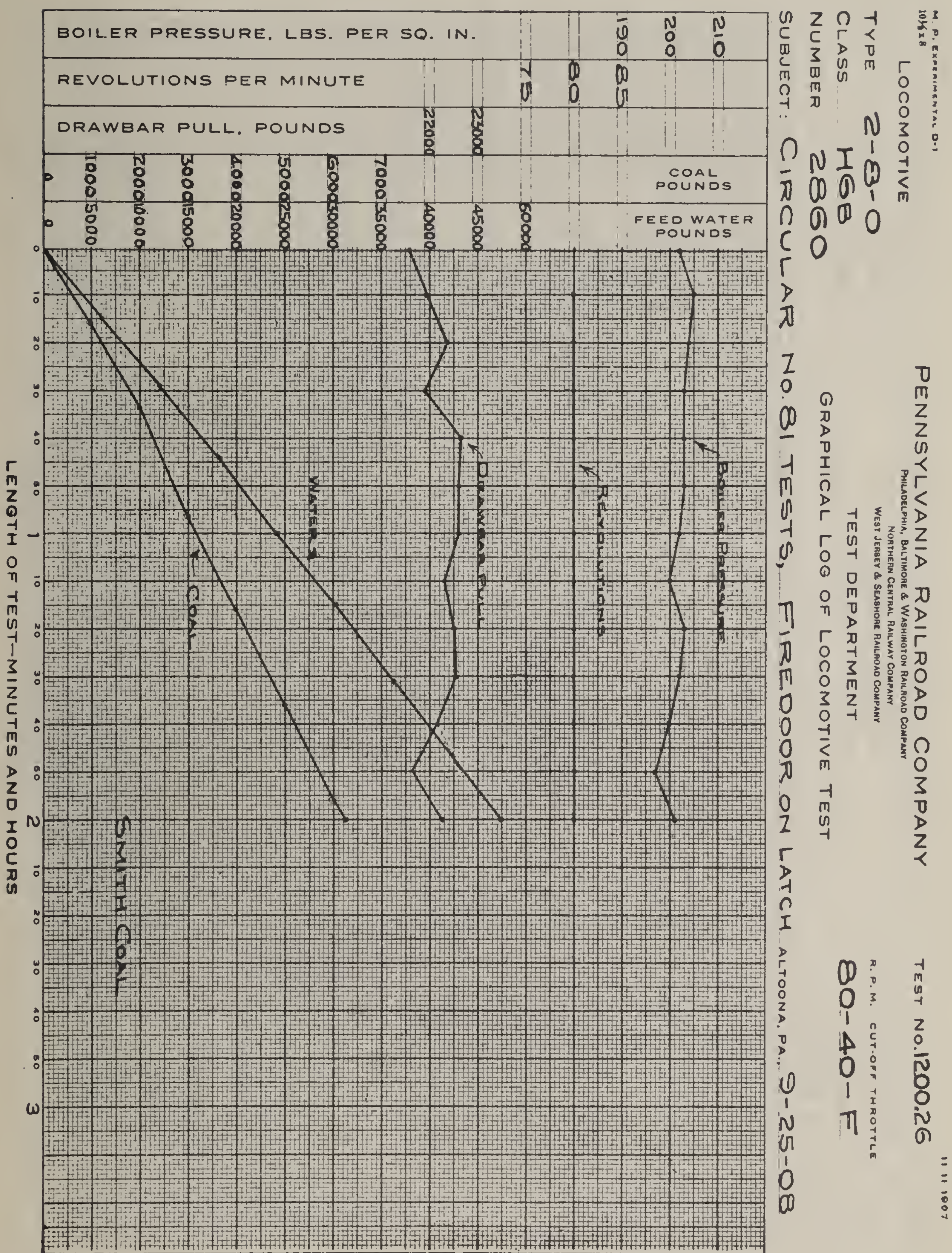
TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE					
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	SMOKE NUMBER	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)
	214	379	380	381		265	383	384	385	398	399
1200.114A	18620				1.4	18588	662.5	3.99	28.11		5.24
1200.23	22798				1.8	21910	780.9	4.43	29.19		4.40
1200.27	22259				1.2	21659	773.2	4.15	28.79		4.70
1200.108	30537				2.0	24586	1095.3	4.54	27.88		4.12
1200.114	19004				1.5	18829	671.1	4.41	28.32		4.74
1200.26	22765				1.6	22070	786.6	3.90	28.94		5.00
1200.108A	30771				2.1	24135	1075.2	4.62	28.62		4.05

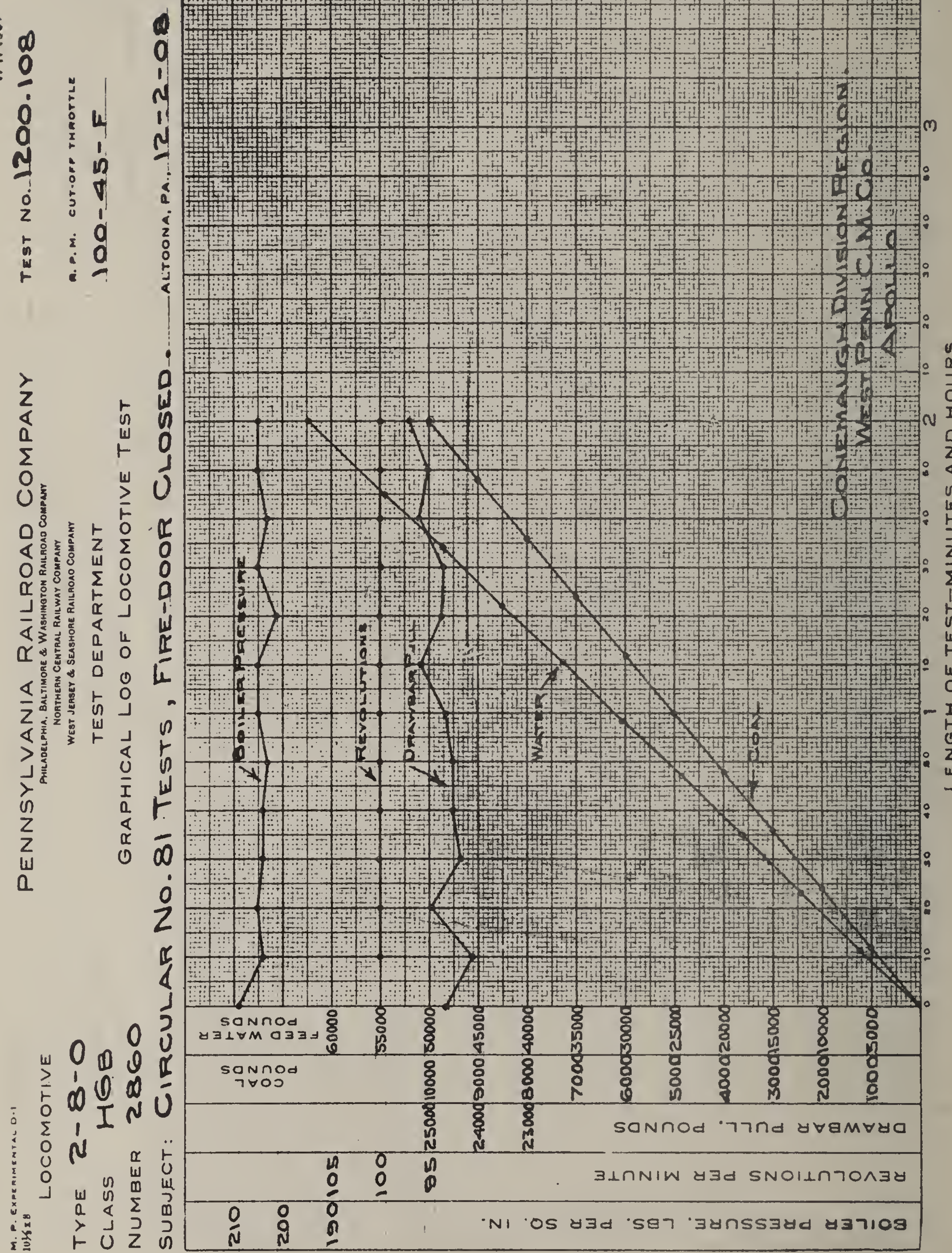

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.114A
R. P. M. CUT-OFF THROTTLE
80-30-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No. 81 TESTS, FIREDOOR CLOSED
ALTOONA, PA. 12-7-08
BOILER PRESSURE, LBS. PER SQ. IN.
210
200
190
REVOLUTIONS PER MINUTE
85
80
75
DRAWBAR PULL, POUNDS
20000
19000
COAL POUNDS
0
1000
2000
3000
4000
5000
6000
7000
FEED WATER POUNDS
0
5000
10000
15000
20000
25000
30000
35000
40000
BOILER PRESSURE
REVOLUTIONS
DRAW-BAR PULL
WATER
COAL
TEST STOPPED ON ACCOUNT OF HEATED BEARING OF SUPPORTING WHEEL AXLE
PRESTON COAL
LENGTH OF TEST—MINUTES AND HOURS

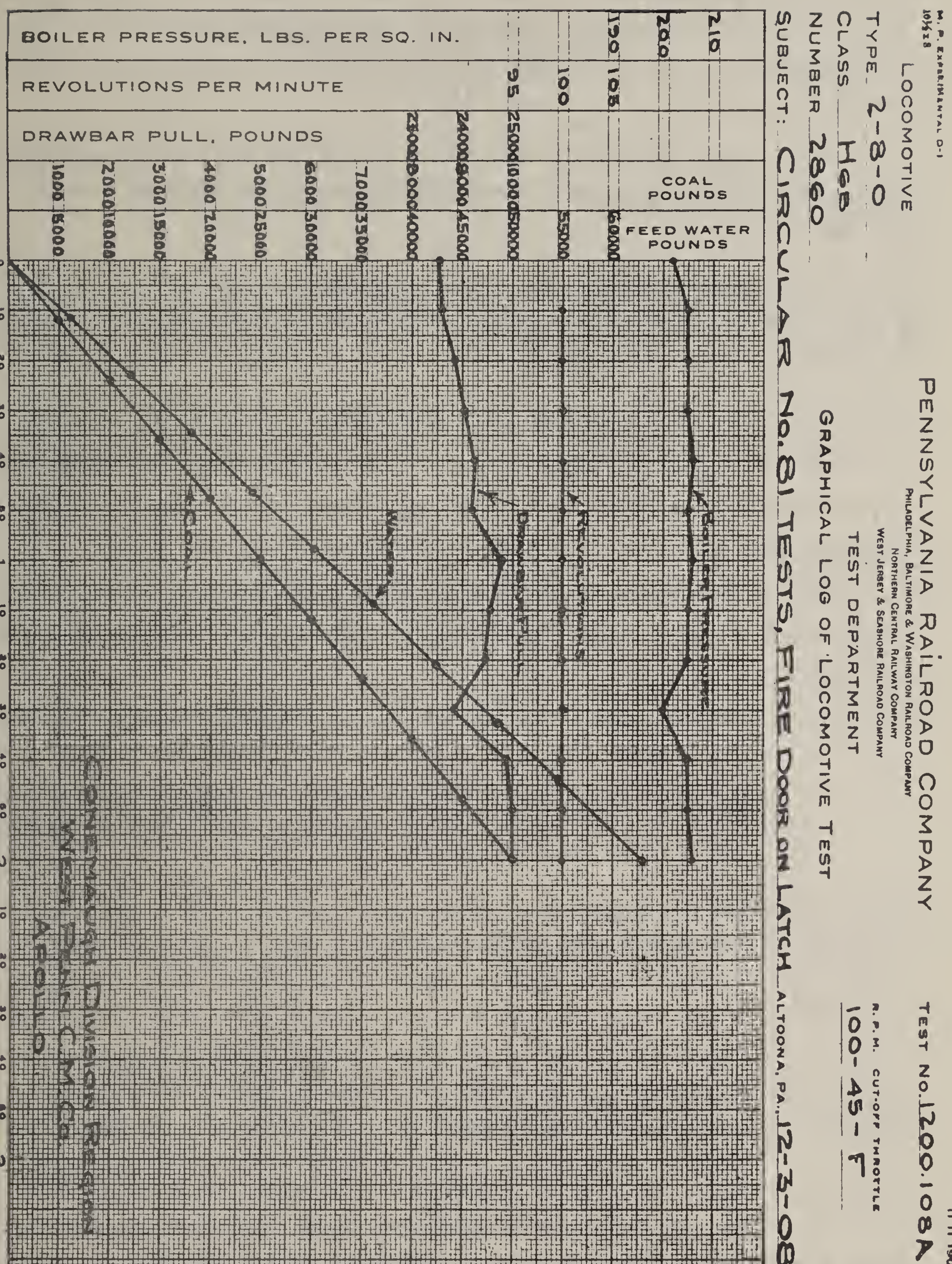

M. P. Experimental D-1
10½x8
11.11 1907
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Locomotive
Type 2-8-0
Class H6b
Number 2860
Test No. 1200,114
R. P. M. Cut-off Throttle
80-30-F
Subject: Circular No. 81 Test, Firedoor on Latch
Altoona, Pa. 12-5-08
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Preston Coal
Length of Test—Minutes and Hours


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No.81 TESTS, FIREDOOR CLOSED
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No.1200.23
R.P.M. CUT-OFF THROTTLE
80-40-F
ALTOONA, PA. 9-24-08
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
SMITH COAL
LENGTH OF TEST—MINUTES AND HOURS


M. P. Experimental O-1
11-1907
Locomotive
Type 2-8-0
Class H6b
Number 2860
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.27
R. P. M. Cut-off Throttle
80-40-F
Subject: Circular No. 81, Firedoor Closed
Altoona, Pa., 9-26-08
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Smith Coal
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Length of Test—Minutes and Hours


M. P. EXPERIMENTAL D-1
10½ x 8
11 11 1907
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.26
R. P. M. CUT-OFF THROTTLE
80-40-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No. 81 TESTS, FIREDOOR ON LATCH ALTOONA, PA., 9-25-08
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
SMITH COAL
LENGTH OF TEST—MINUTES AND HOURS


M. P. Experimental D-1
10½x8
Locomotive
Type 2-8-0
Class H6b
Number 2860
Subject: Circular No. 81 Tests, Fire-door Closed.
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.108
R.P.M. Cut-off Throttle
100-45-F
Altoona, Pa., 12-2-08
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Conemaugh Division Region.
West Penn C.M.Co.
Apollo
Length of Test—Minutes and Hours


M. P. EXPERIMENTAL D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No. 81 TESTS, FIRE DOOR ON LATCH
ALTOONA, PA., 12-3-08
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.108A
R.P.M. CUT-OFF THROTTLE
100- 45- F
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
LENGTH OF TEST—MINUTES AND HOURS
CONEMAUGH DIVISION REGION
WEST PENN C.M.Co.
APOLLO

At medium and high rates of evaporation, the evaporation per pound of coal is in favor of the door on the latch. At 80 R. P. M. and 40 per cent. cut-off the increase in evaporation per pound of coal with the door on the latch is about 12 per cent. When the locomotive is operated at 100 R. P. M. and 45 per cent. cut-off, the firing must be at a rapid rate and the fire door is open a large part of the time.

23. Little difference would be expected between the closed and open positions under these conditions of maximum power of the locomotive.

24. There cannot be much dependence placed upon the smoke indications. They show about the same average smoke for each method of firing.

Fire Not Cleaned.

25. To observe the effect of a fire that has not had the ashes cleaned out before starting, tests were made without cleaning the fire and the test run without shaking the grates.

26. These tests were made with Eureka No. 6 coal and Pittsburgh Coal Company's coal. The analyses of these coals are as follows:

	Coals	
	Eureka No. 6	Pittsburgh
Fixed Carbon, per cent	57.35	47.86
Volatile Combustible, per cent	30.03	37.02
Moisture, per cent	.98	2.33
Ash, per cent	11.64	12.79
	100.00	100.00
Sulphur, separately, per cent	1.81	2.38
B. T. U.'s per pound of dry coal	13529	12281

27. Test No. 1297 is shown with these tests for comparison. It is a test run under normal conditions where the fire is clean and the grates are shaken.

28. Test No. 1200.6 was run without any shaking of the grates and with a fire that had not been cleaned since running a test on the previous day. This test 1200.6 was followed by one

M. P. 394 A—Sixth Sheet
8 x 10½

7 6 1907

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

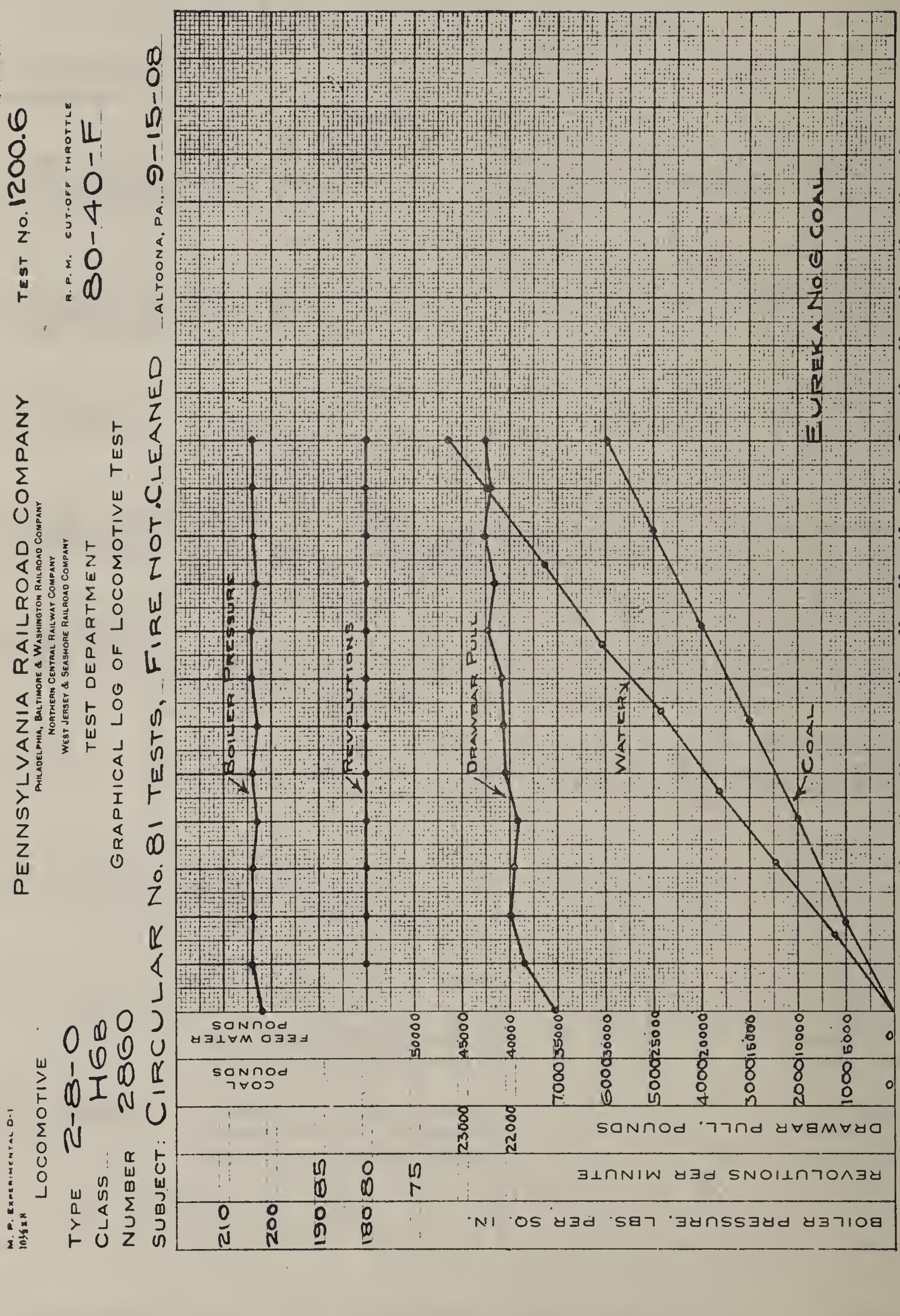
FUEL: EUREKA No. 6
PITTSBURG

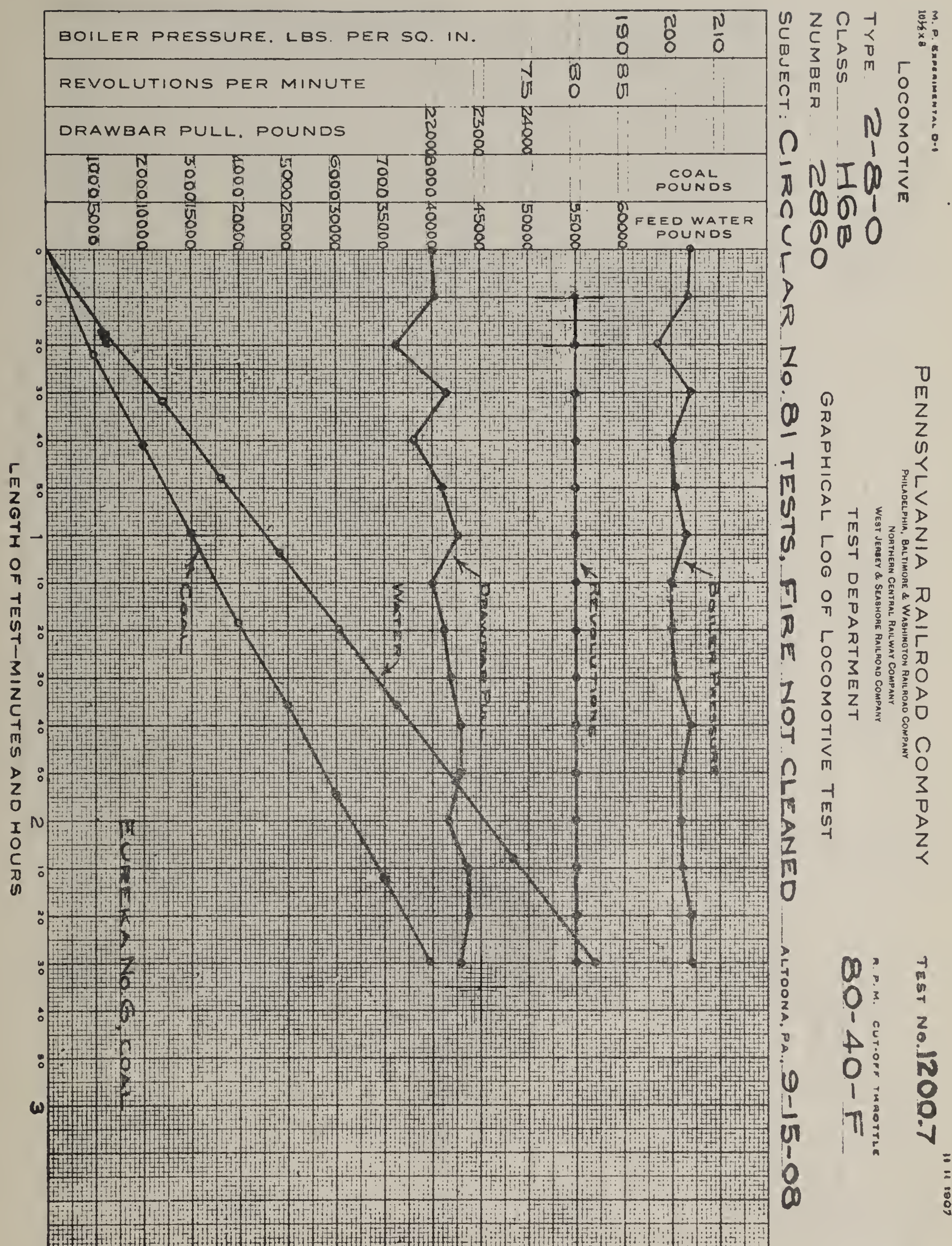
SUBJECT: CIRCULAR No. 81 TESTS ALTOONA, PA., 12-21-08

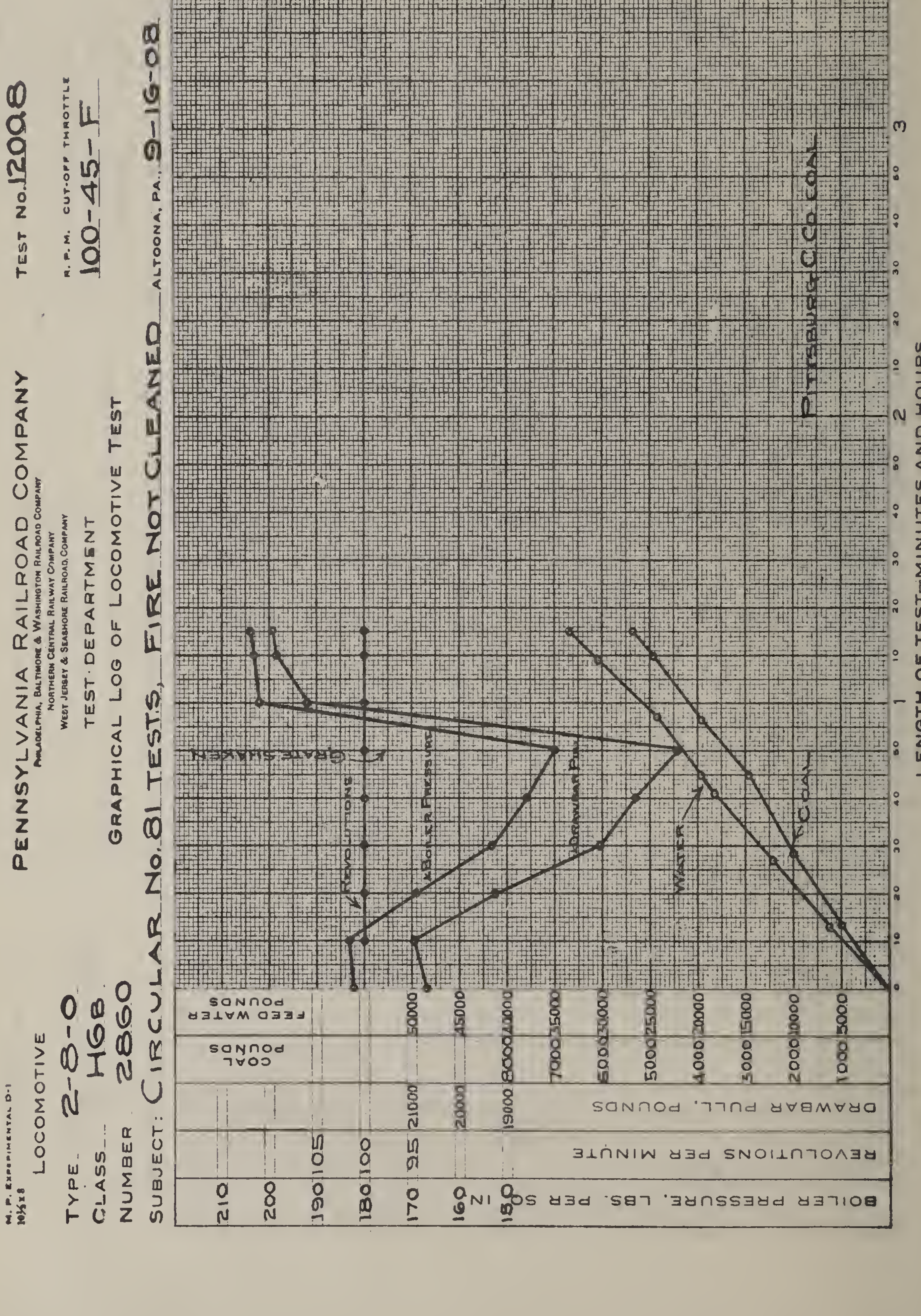
TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	FIRE CONDITION	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1297	80-40-F	2	13.31	FULL		CLEAN, GRATE SHAKEN	203.8	3.5	.1	13529	68
1281	100-45-F	2	16.71	"		"	202.0	5.7	.1	12447	20
1200.6	80-40-F	2	13.31	"		NOT CLEANED	203.6	3.5	.1	13529	58
1200.7	80-40-F	2.5	13.31	"		"	202.0	4.3	.1	13529	84
1200.8	100-45-F	.75	16.64	"		"	162.2	5.3	.1	12364	68

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	COAL	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1297	2971	61.06	22918	27323	10.91	9.20	792.0	65.68	EUREKA		
1281	4408	90.59	31747	37764	15.07	8.57	1094.6	66.50	PITTS.		
1200.6	2956	60.75	23241	27690	11.05	9.37	802.6	66.89	EUREKA		
1200.7	3148	64.69	22715	27076	10.81	8.60	784.8	61.39	EUREKA		
1200.8	3820	78.50	26279	31187	12.45	8.16	904.0	63.74	PITTS.		

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	SMOKE NUMBER
	214	379	380	381		265	383	384	385	398	399	
1297	22630					22454	800.3	3.71	28.28		5.07	1.6
1281	31345					23185	1032.9	4.27	30.35		4.69	2.0
1200.6	22841					21906	780.7	3.79	29.26		4.96	1.6
1200.7	22426					22083	787.0	4.00	28.50		4.70	2.1
1200.8	25961					18097	806.2	4.74	32.20		4.34	2.2


M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 2860
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Test No. 1200.6
R. P. M. Cut-off Throttle
80-40-F
Subject: Circular No. 81 Tests, Fire Not Cleaned
Altoona, Pa., 9-15-08
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Eureka No. 6 Coal
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Length of Test—Minutes and Hours


M. P. Experimental D-1 10½x8
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No. 81 TESTS, FIRE NOT CLEANED
ALTOONA, PA., 9-15-08
PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.7
R. P. M. CUT-OFF THROTTLE
80-40-F
11 11 1907
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
85
80
75
24000
23000
22000
8000
7000
6000
5000
4000
3000
2000
1000
60000
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
Boiler Pressure
Revolutions
Drawbar Pull
Water
Coal
Eureka No. 6, Coal
LENGTH OF TEST—MINUTES AND HOURS



M. P. Experimental D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No. 81 TESTS, FIRE NOT CLEANED
ALTOONA, PA., 9-16-08
PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 12008
R. P. M. CUT-OFF THROTTLE
100-45-F
BOILER PRESSURE, LBS. PER SQ IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
REVOLUTIONS
BOILER PRESSURE
DRAWBAR PULL
WATER
COAL
GRATE SHAKEN
PITTSBURG C. CO. COAL
LENGTH OF TEST—MINUTES AND HOURS

(No. 1200.7) without cleaning the fire, and finally test No. 1200.8 was run without cleaning the fire. This last test was made with Pittsburgh Coal Company's coal, and it was at a higher speed and longer cut-off than the others.

29. While the evaporation per pound of coal is rather low in test 1200.7, no serious difficulty developed in the firebox until test 1200.8 was started. In this test the effect of the ashes in the fire began to have a very marked effect and the boiler pressure could not be kept up. When the pressure had fallen to 140 pounds the grates were well shaken for the first time, and the pressure increased from 140 to 202 pounds in ten minutes. The results of these tests in fuel and evaporation are shown in the following table:

Test Number	Speed in Miles per Hour	Cut-off Per Cent.	Length of Run, Miles	Boiler Pressure Average	Draft in Smokebox	Equivalent Evaporation Per Lb. Dry Coal	Condition of Fire
1297	13.3	40	26.6	203.8	3.5	9.20	Clean and grates shaken.
1281	16.7	45	32.4	202.0	5.7	8.57	" " " "
1200.6	13.3	40	26.6	203.6	3.5	9.37	Not clean, grates not shaken.
1200.7	13.3	40	33.3	202.0	4.3	8.60	" " " "
1200.8	16.6	45	12.5	162.2	5.3	8.16	" " " "

30. The draft increased by nearly one inch, or about 30 per cent., as the ashes accumulated in the fire.

31. While tests 1200.6 and 1200.7 show a good boiler pressure, this pressure was maintained at the expense of the coal, as in test 1200.7 the evaporation per pound of coal is 8.60 pounds, when with a clean fire it was 9.20 pounds.

32. Test 1200.6 was started with a fire that had not been cleaned over night, and No. 1200.8 was started under similar conditions. There were long intervals between the runs.

33. When the grates were first shaken in test 1200.8 they had not been moved for 44 hours, and the locomotive had run a total distance of over 100 miles, burning during the tests 26,000 pounds of coal, and a considerable amount between the tests. This latter quantity of coal may be estimated at about 2500 pounds.

34. Tests 1297 and 1281 have been taken as showing the normal performance of the locomotive with the fire clean and grates shaken during the test. The tests shown are at two different speeds and cut-offs. The evaporative results at the same speed, only, should be compared; as, for instance, test 1297 may be compared with 1200.6 and 1200.7, while 1281 may be compared with 1200.8.

35. The quality of the coal has much to do with the amount of cleaning that the fire will need. These two coals do not clinker, but have the average amount of ash.

Irregular Boiler Feeding.

36. In test No. 1200.113 the water level in the boiler was not kept at one place as is usual, but the injector was used intermittently. The water level was raised to the top of the gage glass and the injector shut off until the level had fallen to the bottom of the glass, a distance of about six inches. This irregular feeding was continued during the test, the locomotive wasting steam at the safety valves when the water level was falling, and the pressure decreasing when the injector was put on at its full capacity.

37. The fireman fired the locomotive at a nearly uniform rate. The engineman and fireman were then not assisting each other in maintaining the steam pressure, but each worked independently.

38. The result upon the boiler pressure is very clear from an inspection of the graphical log for this test No. 1200.113. The average pressure for the test is but 195.5 pounds. The range in pressure is from 165 to 205 pounds.

39. The evaporation per pound of coal is very low in this test. It is but 7.67 pounds equivalent evaporation per pound of dry coal, where under the same running conditions but with regular boiler feeding it is 9.0 pounds. With the irregular feeding there is a loss in evaporation of 1.33 pounds of water per pound of coal, or about 15 per cent.

40. The weight of coal that is needed for this test with regular boiler feeding is 3093 pounds per hour, as shown by test No. 1200.115, while with the irregular feeding 3547 pounds are required. This is a loss or waste of coal of 450 pounds per hour, or 12½ per cent. For a 100-mile run the coal fired would be 23,238 pounds with regular boiler feeding and 26,648 pounds with irregular feeding—a difference of 3410 pounds of coal.

M. P. 394 A—Sixth Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

FUEL: PRESTON & EUREKA No.6

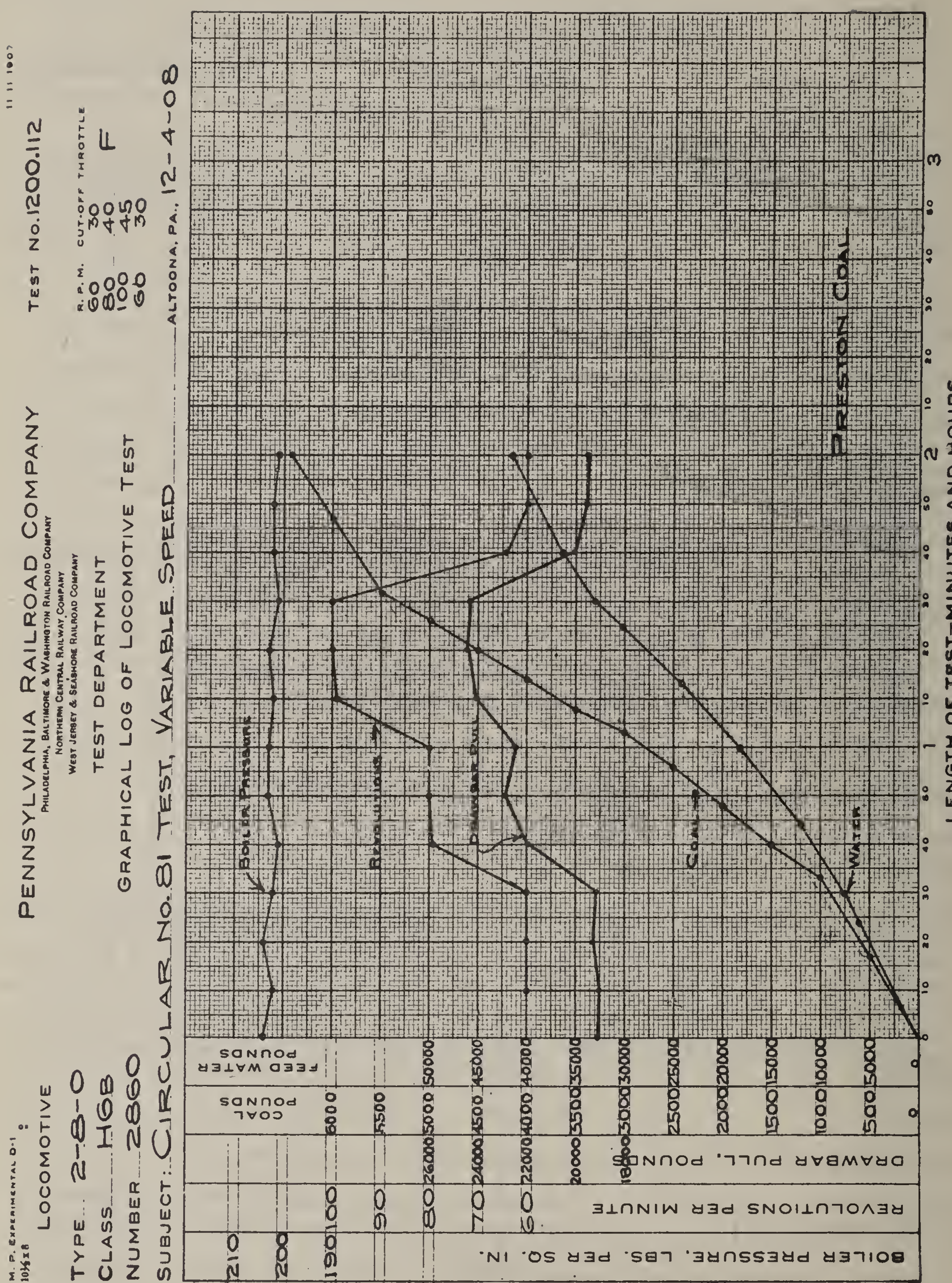
SUBJECT: CIRCULAR No. 81 TESTS

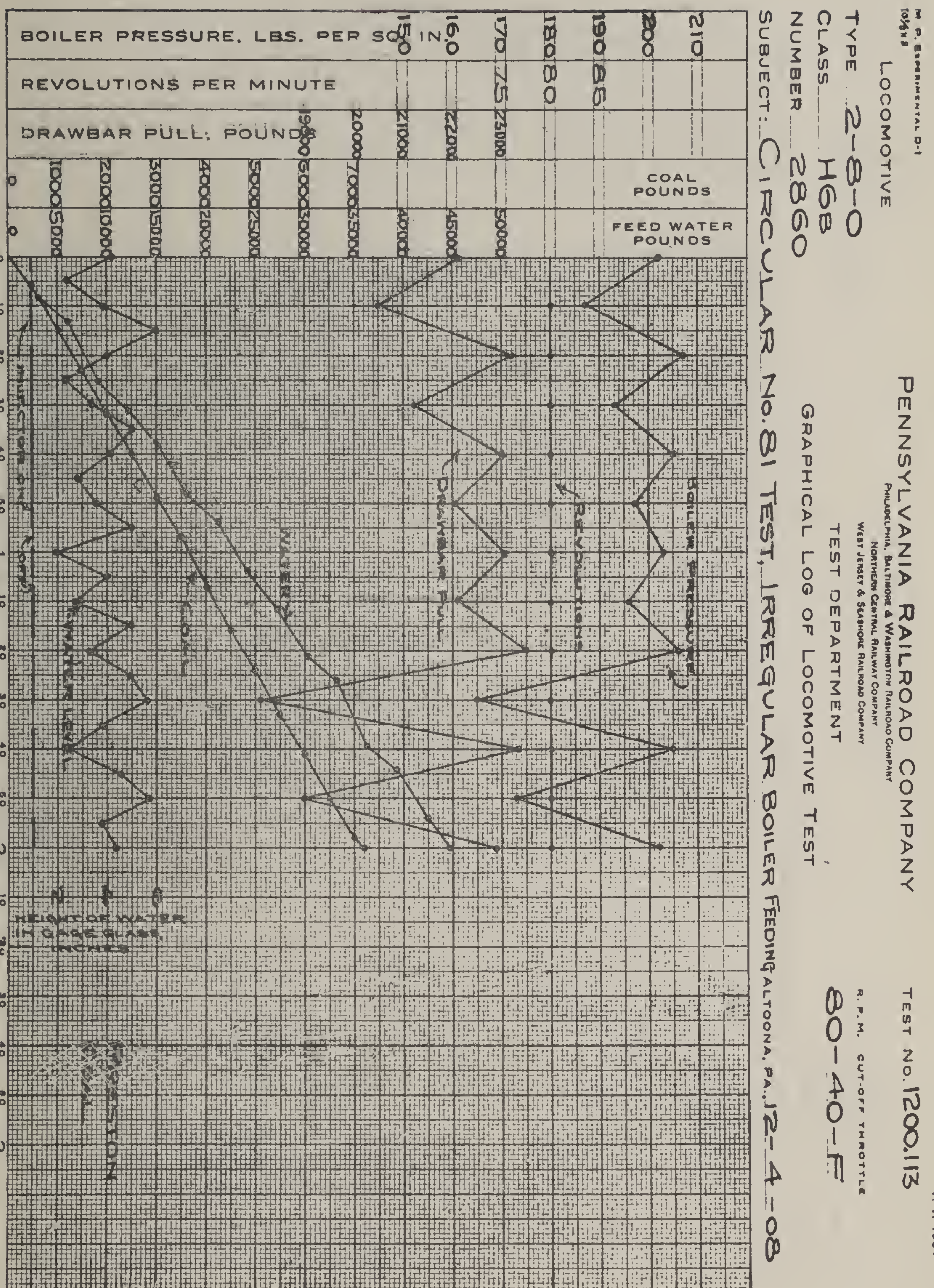
ALTOONA, PA., 12-21-08

TEST NUMBER	RUNNING CONDITIONS: Test Designation	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.112	60 - 30 - F 80 - 40 - F 100 - 45 - F	2	AVERAGE 12.95	FULL		VARIABLE SPEED	202.3	3.2	.2	12183	61
1200.113	80-40-F	2	13.19	"		IRREGULAR BOILER FEED	195.5	3.5	.2	12183	94
1200.5	80-40-F	2	13.31	"		IRREGULAR FIRING	197.9	3.5	.1	13529	37
1200.115	80-40-F	2	13.19	"	REGULAR FIRING	REGULAR BOILER FEED	204.2	3.6	.1	12183	52
1275	80-40-F	2.5	13.36	"		REGULAR FIRING	201.6	3.5	.1	13743	70

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.112	3158	64.90	20753	25209	10.06	7.98	730.7				
1200.113	3547	72.89	22396	27205	10.86	7.67	788.6				
1200.5	3347	68.78	23121	27523	10.99	8.22	797.8	58.68			
1200.115	3093	63.56	22833	27822	11.11	9.00	806.4	71.34			
1275	3135	64.43	23938	28449	11.36	9.07	824.6	63.74			

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	COAL	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	SMOKE NUMBER
	214	379	380	381		265	383	384	385	398	399	
1200.112					PRESTON	21228	742.4	4.25	27.62			1.7
1200.113					PRESTON	21671	772.4	4.59	27.55			2.2
1200.5	22167				EUREKA	21638	771.2	4.34	28.74		4.33	1.5
1200.115	22334				PRESTON	22546	803.5	3.85	27.80		5.43	1.6
1275	23648				EUREKA	22279	794.0	3.95	29.78		4.69	1.8


M. P. Experimental D-1
Locomotive
Type 2-8-0
Class H6B
Number 2860
Subject: Circular No. 81 Test, Variable Speed
Pennsylvania Railroad Company
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
Test Department
Graphical Log of Locomotive Test
Altoona, Pa., 12-4-08
Test No. 1200.112
R.P.M. 60 80 100 60
Cut-off 30 40 45 30
Throttle F
Boiler Pressure, Lbs. per Sq. In.
Revolutions per Minute
Drawbar Pull, Pounds
Coal Pounds
Feed Water Pounds
Boiler Pressure
Revolutions
Drawbar Pull
Coal
Water
Preston Coal
Length of Test—Minutes and Hours


M. P. Experimental D-1
10¾ x 8
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No. 81 TEST, IRREGULAR BOILER FEEDING ALTOONA, PA., 12-4-08
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.113
R. P. M. CUT-OFF THROTTLE
80-40-F
11 11 1907
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
WATER LEVEL
INJECTORS ON
OFF
HEIGHT OF WATER IN GAGE GLASS, INCHES
LENGTH OF TEST—MINUTES AND HOURS

M. P. Experimental D-1
10½ x 8

LOCOMOTIVE

TYPE 2-8-0

CLASS H6b

NUMBER 2860

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

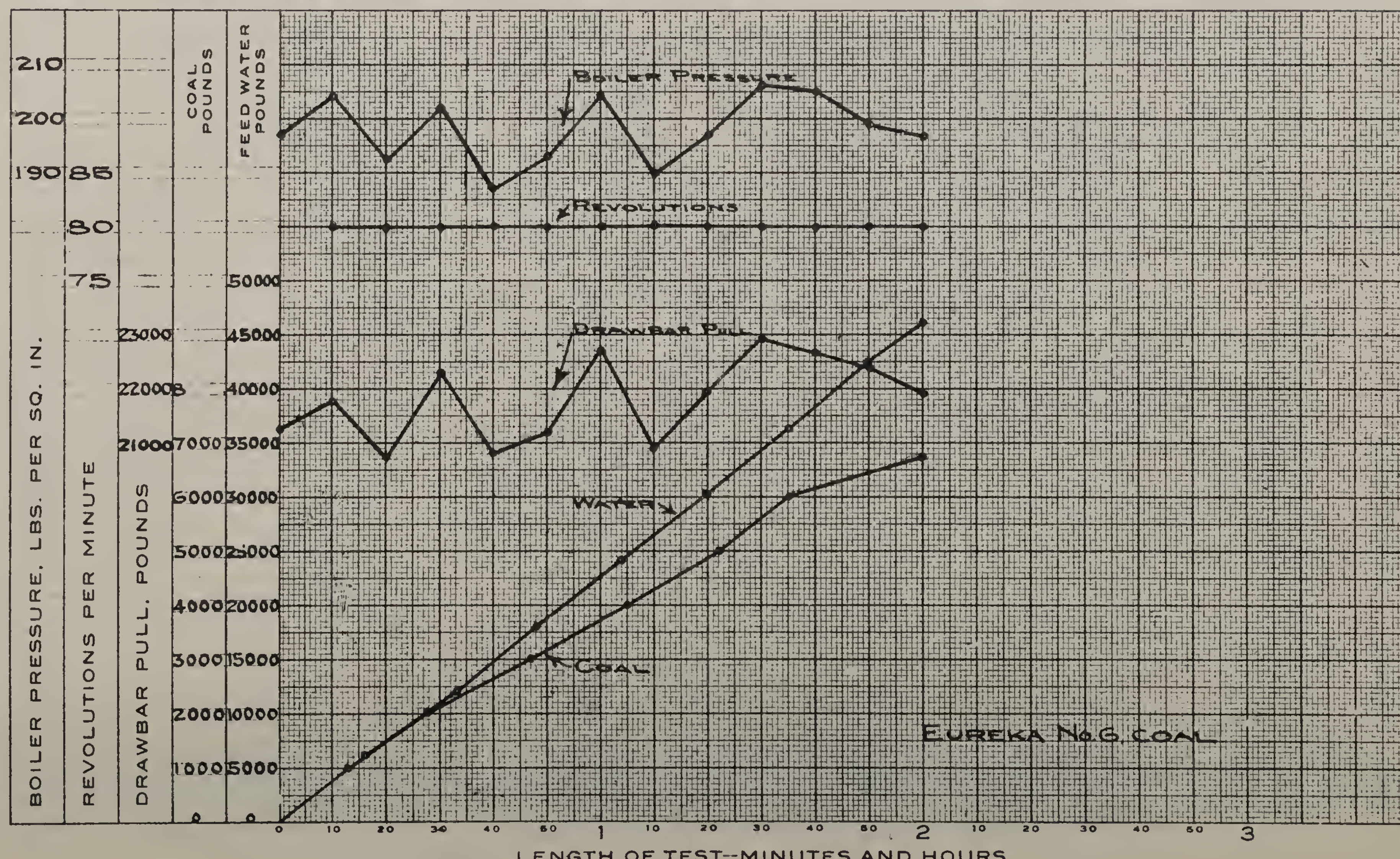
GRAPHICAL LOG OF LOCOMOTIVE TEST

TEST NO. 1200.5

11 11 1907

R. P. M. CUT-OFF THROTTLE
80-40-F

SUBJECT: CIRCULAR No. 81 TESTS, IRREGULAR FIRING ALTOONA, PA., 9-14-08



M. P. Experimental D-1
11-3-28

LOCOMOTIVE

TYPE 2-8-0

CLASS HGB

NUMBER 2860

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

GRAPHICAL LOG OF LOCOMOTIVE TEST

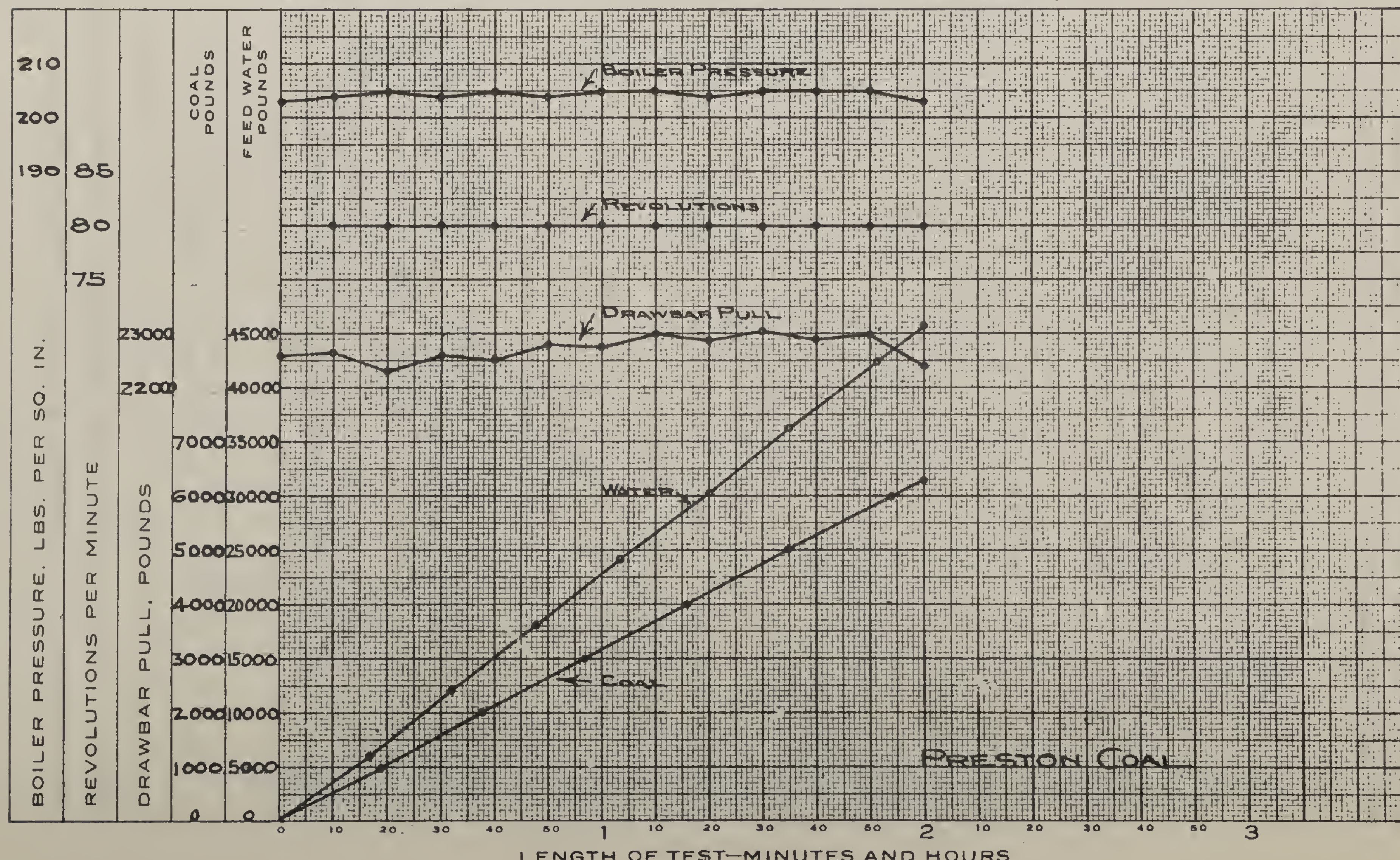
11 11 1907

TEST No. 1200.115

R. P. M. CUT-OFF THROTTLE

80-40-F

SUBJECT: CIRCULAR No. 81 TESTS, REGULAR FIRING & BOILER FEEDING ALTOONA, PA., 12-9-08



Irregular Firing.

41. The firing on the Testing Plant is usually continuous, or nearly so. Small quantities of coal are fired at very short intervals.

42. To determine the effect of irregular or intermittent firing, a test was made by firing six shovelfuls of coal in succession with long intervals between firing. This method of firing resulted in a very irregular boiler pressure, as will be seen by reference to the graphical log of this test, No. 1200.5.

43. The equivalent evaporation per pound of coal with regular firing for these running conditions is 9.07 pounds of water, while with irregular firing it is 8.22 pounds, or a loss in evaporation of nearly 9 per cent.; 3347 pounds of coal were burned per hour with irregular firing, while with regular firing and the same kind of coal 3135 pounds are required.

Variable Speed.

44. A test has been made, No. 1200.112, to conform more nearly to road conditions than is usual on the Testing Plant. This run was at three speeds and cut-offs. The locomotive was run for 30 minutes at 60 revolutions per minute and 30 per cent. cut-off, then for 30 minutes at 80 revolutions and 40 per cent. cut-off, then for 30 minutes at 100 revolutions and 45 per cent. cut-off, finally ending with 30 minutes at 60 revolutions and 30 per cent. cut-off. Thus the test was of two hours' duration, but with the locomotive developing a variable power as in road service. During this test the fireman changed his rate of firing three times to conform to the changed conditions of running. These changes were so quickly made that there was an almost constant boiler pressure.

45. The evaporation per pound of coal, when compared with that for a test at a uniform speed, which is about the same as the average for this test, or 12 miles per hour, shows lower results for the variable speed test. The evaporation for a uniform speed of 80 revolutions is 9 pounds per pound of coal, while for this variable speed test it is but 7.98, or over a pound of water less.

46. The coal consumption per dynamometer horsepower hour for the variable speed test was 4.25 pounds, while for a test with the same kind of coal run at constant speed, which was about the same as the average of the variable speed test, the coal consumption was 3.85 pounds per dynamometer horsepower hour.

Lump Coal and "Run-of-Mine" Coal.

47. On some heavy grades it is the custom of the firemen to lay aside the lumps that can be separated from the finer coal, and to use this lump coal when the locomotive is working hard on a grade with an exhaust that would make holes in a fire composed of fine coal, drawing the lighter particles up against the tube sheet.

48. It would not be possible to run the locomotive at a very low speed and long cut-off on the Testing Plant in order to try out this question of the relative merits of fine and lump coal. There would be great danger of the wheels slipping. To find what difference exists between the evaporation with lumps or with fine coal as an alternative, tests have been made with the same kind of coal in the two forms. The locomotive was operated under a comparatively light load, however.

49. During a series of coal tests a car of Kiskiminetas coal, very lumpy on the top, came to the Testing Plant. Enough of the lumps were picked from the top of the car to make a test, using lump coal only.

50. This test, No. 1200.42, was followed by one, No. 1200.39, in which the same kind of coal was used, but the coal was taken from the bottom of the car, where the coal consisted of both lump and fine coal, or an average "run-of-mine" coal.

51. The results in evaporation are: an equivalent evaporation of 8.61 pounds of water per pound of coal, for the lump coal, and 7.9 pounds for the fine coal or average coal. This is an increase in evaporation of 9 per cent. with the lump coal.

52. On an "E2" locomotive another coal has been tried in two forms, screened and "run-of-mine." The analysis of the two forms of the coal shows:

	Screened.	*Run-of-Mine.*
Ash, in per cent	4.71	6.27
Calorific Value, B. T. U.'s per pound of dry coal	14864	14360

53. The ash is a greater proportion and the heating value less for the "run-of-mine" than the screened coal. The equivalent evaporation with this latter coal was for the screened 8.5 pounds, and but 7.7 pounds with the "run-of-mine" coal. This is an increase in evaporation of 10 per cent. with the screened or lump coal.

M. P. 394 A—Sixth Sheet
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-0
CLASS H.6B.
NUMBER 2860

FUEL: KISKIMINETAS

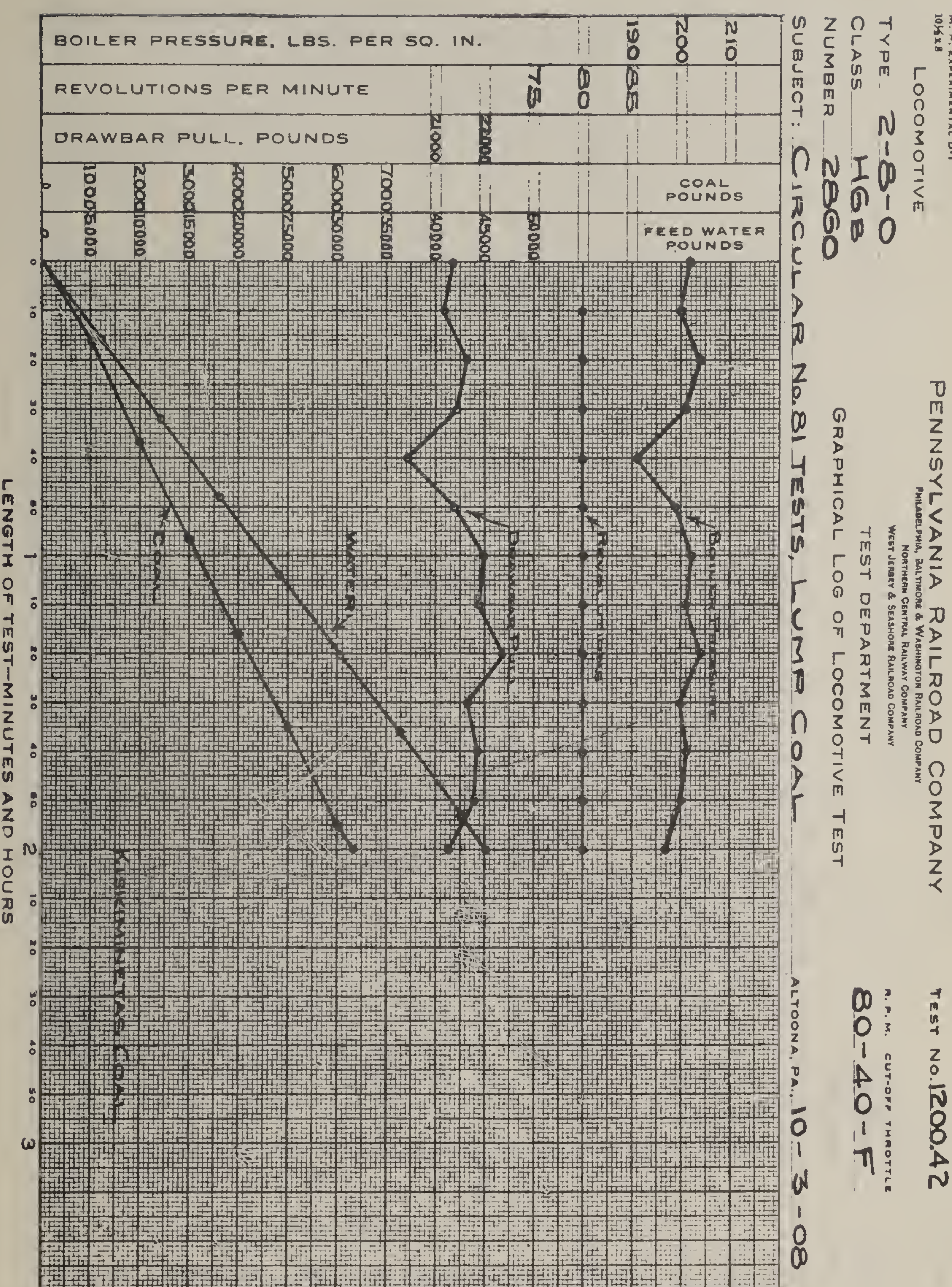
SUBJECT: CIRCULAR No.81 TESTS

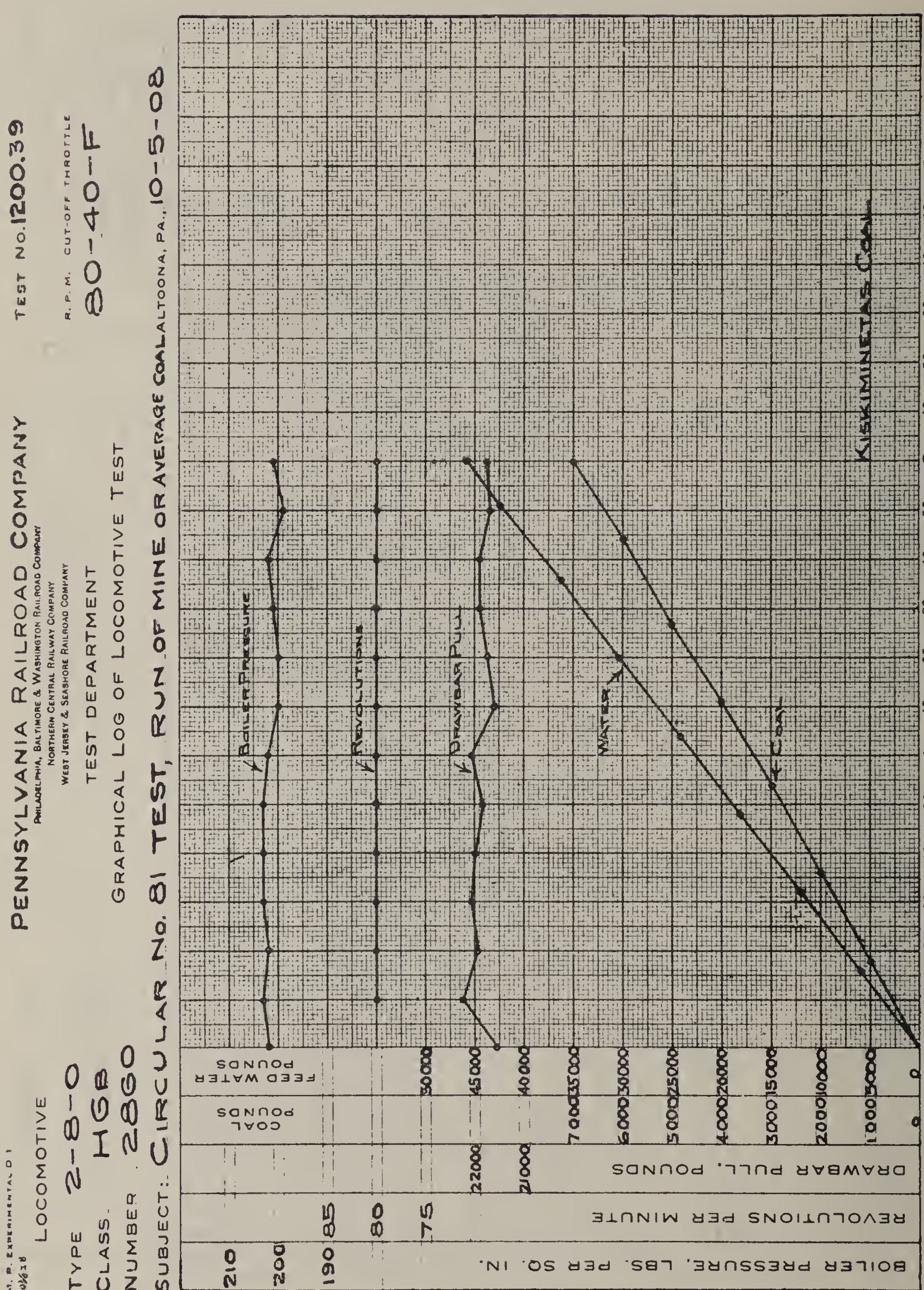
ALTOONA, PA. 10-16-08

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
1200.42	80-40-F	2.0	13.31	FULL		LUMP COAL	200.2	3.5	.1	13506	46
1200.39	80-40-F	2.0	13.31	"		AVERAGE COAL	201.6	3.5	.1	13506	23
1200.11	80-40-F	1.0	13.31	"		HIGH WATER	199.9	3.4	.1	—	—
1200.12	80-40-F	1.0	13.31	"		LOW WATER	199.7	3.4	.1	—	—

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	QUALITY OF STEAM % DRY	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
1200.42	3137	64.47	22564	27012	10.78	8.61	783.0	61.57	—		
1200.39	3472	71.35	22928	27439	10.95	7.90	795.3	5649	—		
1200.11	—	—	22638	—	—	—	—	—	98.16		
1200.12	—	—	22537	—	—	—	—	—	98.45		

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	SMOKE NUMBER
	214	379	380	381		265	383	384	385	398	399	
1200.42	22272	—		—		21381	762.0	4.12	29.23		4.57	1.3
1200.39	22586	—		—		21691	773.1	4.49	29.21		4.20	1.6
1200.11	22337	895.8		24.94		21194	755.4	—	29.57		—	—
1200.12	22285	913.6		24.39		21936	781.8	—	28.50		—	—


M. P. EXPERIMENTAL O-1
10½x8
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1200.42
R. P. M. CUT-OFF THROTTLE
80-40-F
SUBJECT: CIRCULAR No. 81 TESTS, LUMP COAL
ALTOONA, PA., 10-3-08
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
85
80
75
22000
21000
1000
2000
3000
4000
5000
6000
7000
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
KISKIMINETAS COAL
LENGTH OF TEST—MINUTES AND HOURS
1
2
3
11 11 1907



M. P. EXPERIMENTAL 1
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 1200.39
R. P. M. CUT-OFF THROTTLE
80-40-F
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: CIRCULAR No. 81 TEST, RUN OF MINE OR AVERAGE COAL ALTOONA, PA., 10-5-08
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
210
200
190
85
80
75
22000
21000
7000
6000
5000
4000
3000
2000
1000
0
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
KISKIMINETAS COAL
LENGTH OF TEST—MINUTES AND HOURS

54. While enginemen ascribe the better steaming of the locomotive over the heavy grades to the fact that with lump coal the fire is not so much disturbed by the draft, it is also clear that the lump coal is about 10 per cent. better in heating or evaporative value than the average "run-of-mine" coal. This fact probably has more influence upon the good results than has the action of the draft on the fire, although the lump coal gives more opportunity for air to get to the fuel, and thus produces greater efficiency.

High and Low Water Level.

55. While not referred to in the circular, tests have been made of the effect upon the quality of steam of a high or a low water level in the boiler. These tests are Nos. 1200.11 and 1200.12. The percentage of moisture in the steam as measured by a throttling calorimeter on the steam dome is the same with the water level high or low. The steam used per horsepower hour, both indicated and drawbar horsepower, shows more steam used when the water level in the boiler was high. This would indicate that there was more moisture in the steam when carried at a high level than when carried at a low level, but the calorimeter does not confirm this and the tests are not conclusive. It is probable that with the locomotive boiler level, as it is on the Testing Plant, the range ($4\frac{1}{2}$ inches) in height of water level is too small to show differences in moisture in the steam. The low water level was one-half inch above the bottom of the gage glass, and the high level 5 inches above the bottom of glass.

56. It is not possible to reproduce on the Testing Plant some of the conditions met with in road service; as, for instance, the surging of the water due to the quick application of the brakes or a sudden change in grade. With a high water level this movement of the water may carry water to the cylinders.

57. It has been observed, however, on the Testing Plant, that if the water level is within about one-half inch of the top of the gage, water will be lifted out of the boiler if the safety valve blows.

Coal Fired at Various Rates.

58. Some trials have been made to establish the fact that the amount of coal that the fireman uses is in reality the correct amount. The question has arisen as to what would happen if the fireman, having fired for a certain test, were to fire for the same conditions of speed and cut-off again, but with a greater or

M. P. 394 A—Sixth Sheet
8 x 10½

7 8 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H6B
NUMBER 2860

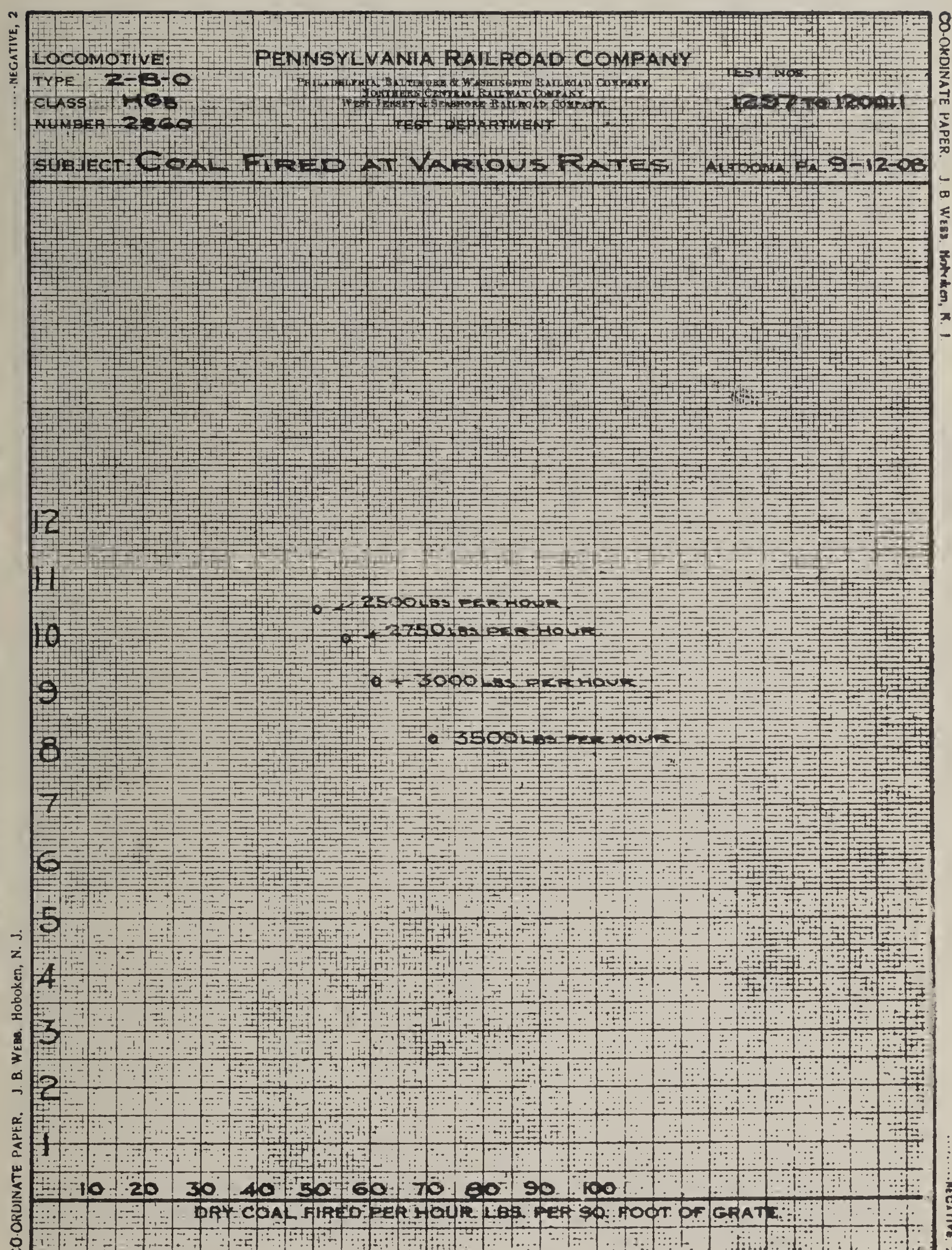
FUEL: EUREKA, No. 6

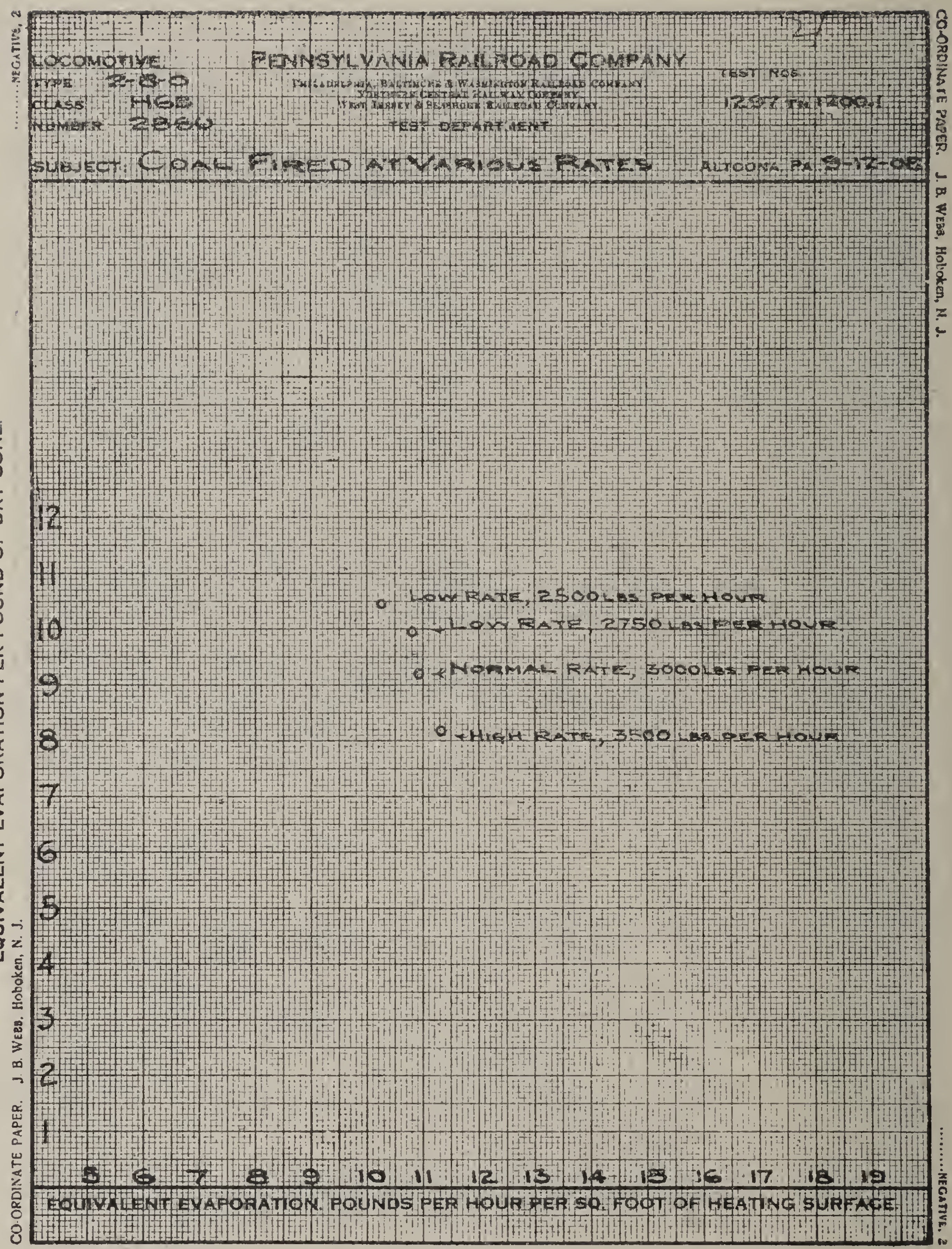
SUBJECT: COAL FIRED AT VARIOUS RATES ALTOONA, PA., 9-12-08

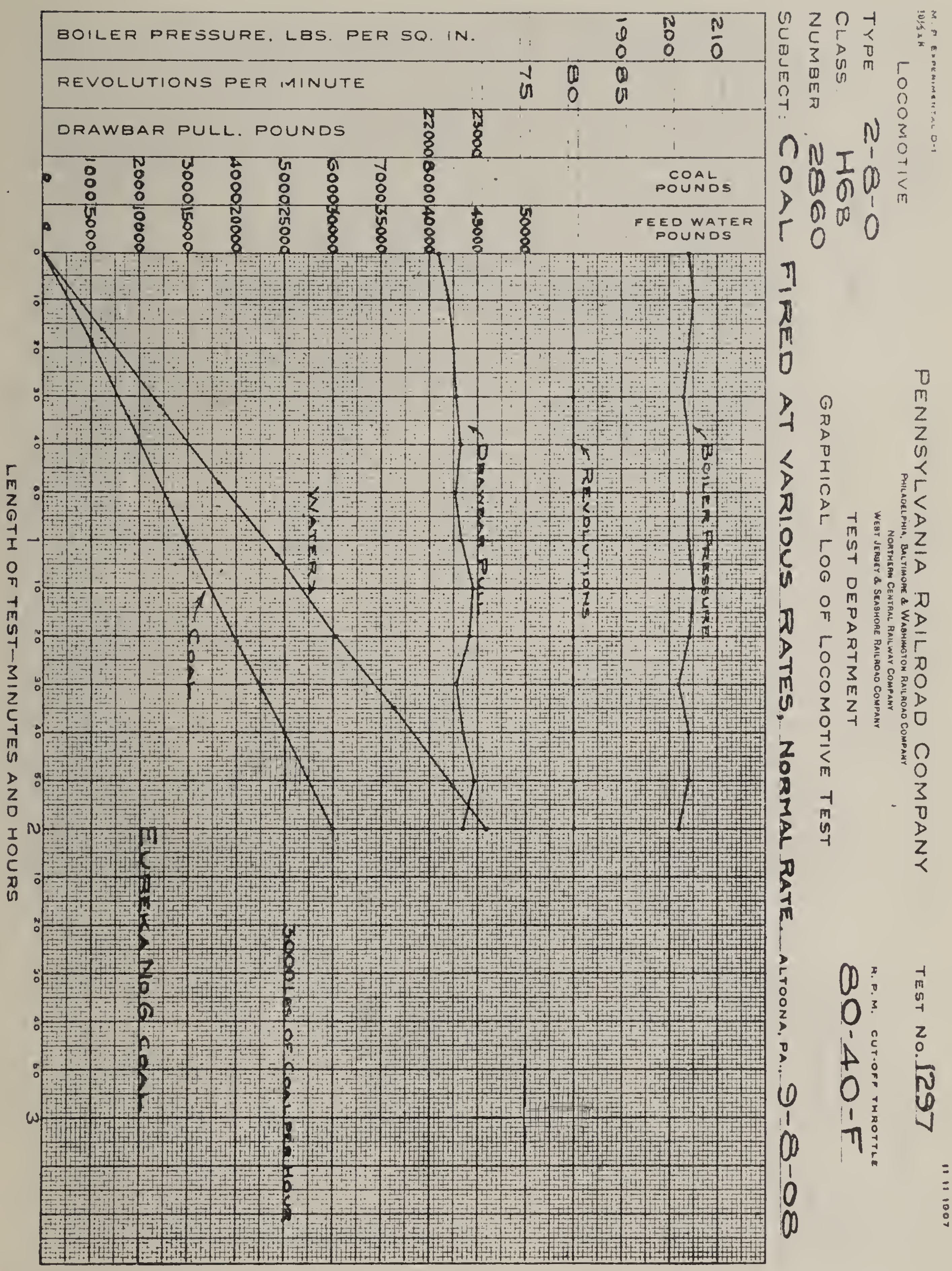
TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	KIND OF COAL	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B.T.U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	226	248	238
1297	80-40-F	2	13.31	FULL		EUREKA	203.8	3.5	.1	13529	68
1298	80-40-F	2	13.31	"		"	203.7	3.6	.1	13529	77
1299	80-40-F	1	13.31	"		"	187.6	3.6	.1	13529	
1200.1	80-40-F	1	13.31	"		"	201.0	3.3	.1	13529	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		230	230
1297	2971	61.06	22918	27323	10.91	9.20	792.0	65.68			
1298	3466	71.23	23798	28372	11.32	8.19	822.4	58:47			
1299	2476	50.88	21623	25689	10.25	10.45	749.8	74.60			
1200.1	2723	55.96	22740	27102	10.82	9.95	785.6	71.03			

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE					
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., Based on Fuel
	214	379	380	381		265	383	384	385	398	399
1297	22630					22454	800.3	3.71	28.28		5.07
1298	22624					22166	790.0	4.39	28.64		4.29
1299	21339					19984	712.2	3.48	29.96		5.41
1200.1	22414					22021	784.8	3.47	28.56		5.42


PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY.
NORTHERN CENTRAL RAILWAY COMPANY.
WEST JERSEY & SEASHORE RAILROAD COMPANY.
TEST DEPARTMENT
LOCOMOTIVE:
TYPE 2-8-0
CLASS H6b
NUMBER 2860
TEST NOS.
SUBJECT: COAL FIRED AT VARIOUS RATES
ALTOONA, PA. 9-12-08
2500 LBS PER HOUR
2750 LBS PER HOUR
3000 LBS PER HOUR
3500 LBS PER HOUR
EQUIVALENT EVAPORATION PER POUND OF DRY COAL.
12
11
10
9
8
7
6
5
4
3
2
1
10 20 30 40 50 60 70 80 90 100
DRY COAL FIRED PER HOUR LBS. PER SQ. FOOT OF GRATE.
CO-ORDINATE PAPER. J. B. WEBB. Hoboken, N. J.
NEGATIVE, 2


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
PENNSYLVANIA RAILROAD COMPANY
TEST DEPARTMENT
TEST NOS.
1297 TO 1400.1
SUBJECT: COAL FIRED AT VARIOUS RATES
ALTOONA, PA. 9-12-06
LOW RATE, 2500 LBS. PER HOUR
LOW RATE, 2750 LBS. PER HOUR
NORMAL RATE, 3000 LBS. PER HOUR
HIGH RATE, 3500 LBS. PER HOUR
EQUIVALENT EVAPORATION PER POUND OF DRY COAL.
EQUIVALENT EVAPORATION. POUNDS PER HOUR PER SQ. FOOT OF HEATING SURFACE.
CO-ORDINATE PAPER. J. B. WEBB, Hoboken, N. J.
NEGATIVE, 2


LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
SUBJECT: COAL FIRED AT VARIOUS RATES, NORMAL RATE.
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1297
M. P. M. CUT-OFF THROTTLE
80-40-F
ALTOONA, PA., 9-8-08
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
3000 LBS OF COAL PER HOUR
EUREKA No 6 COAL
LENGTH OF TEST—MINUTES AND HOURS

M.P. - Experimental D-1 10/1/08 11 11 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

Test Department

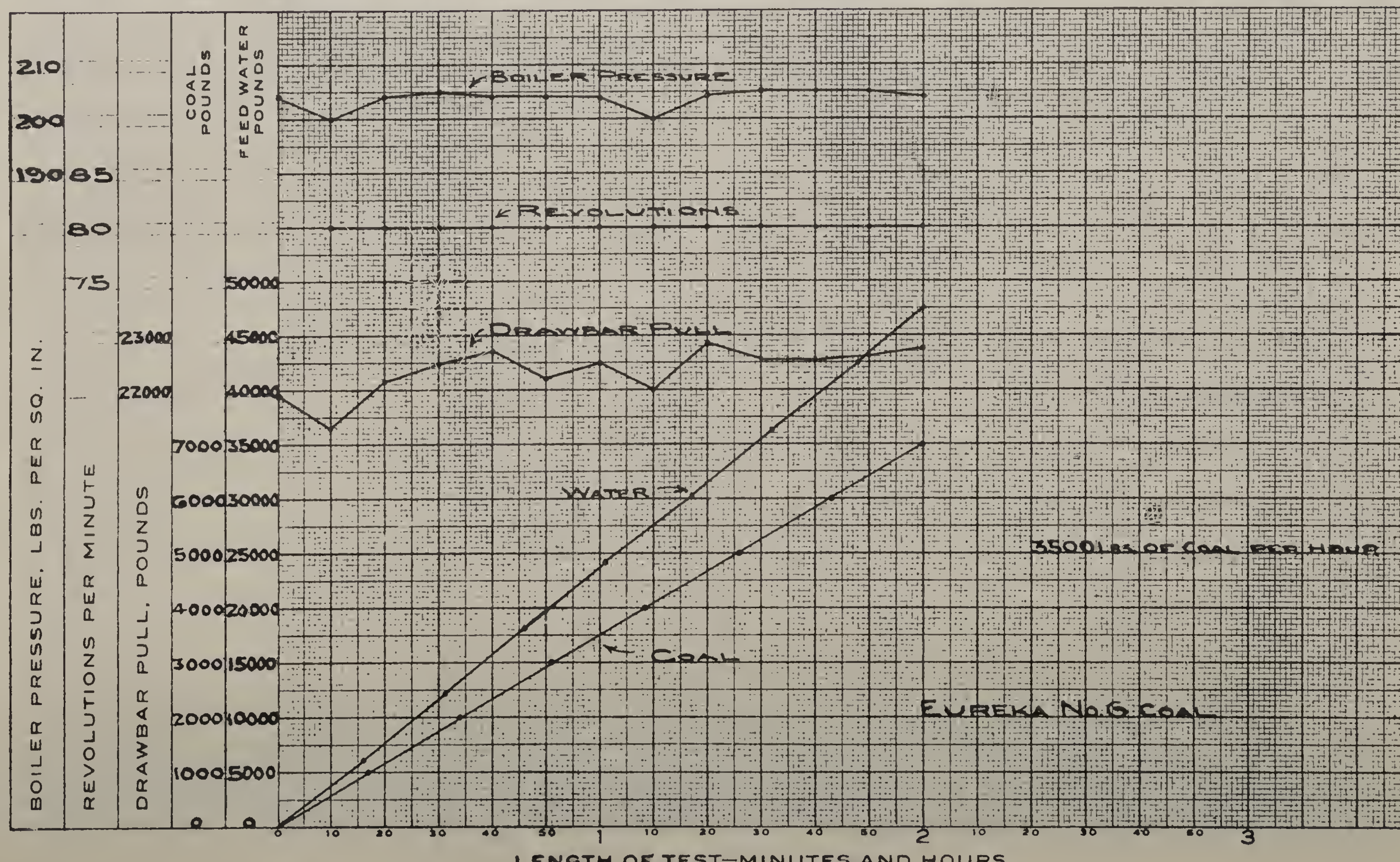
Graphical Log of Locomotive Test

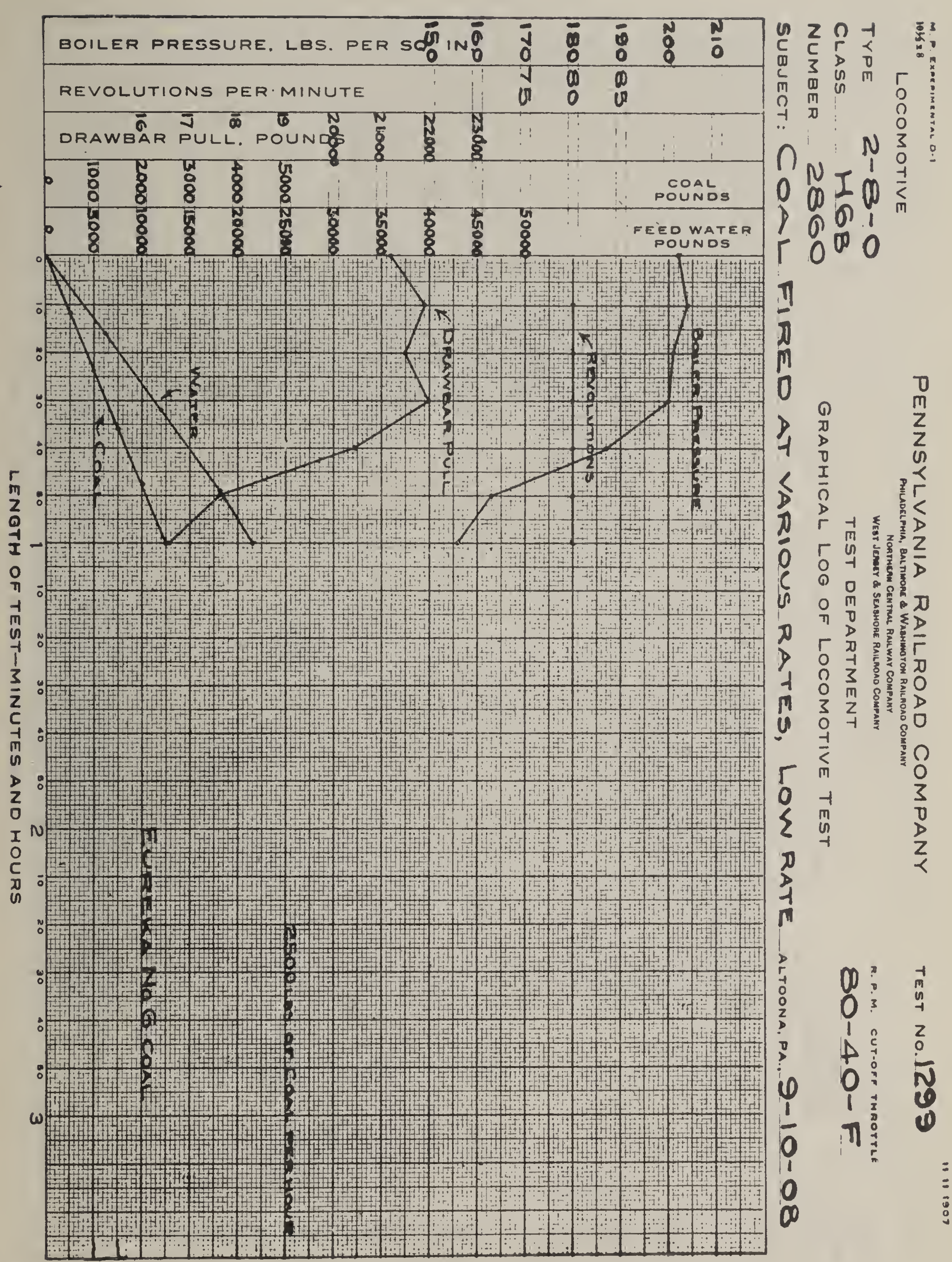
Test No. 1298

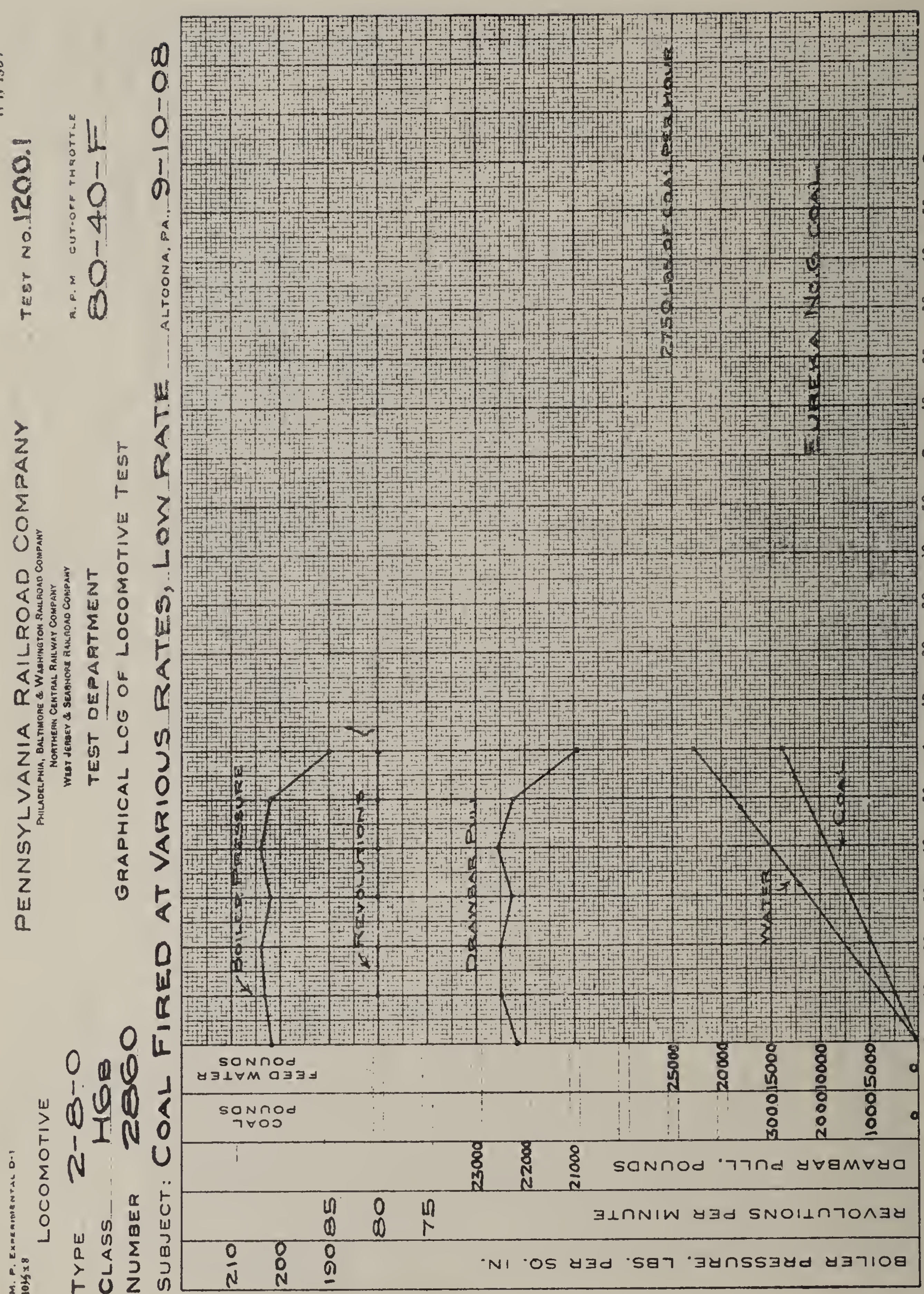
R. P. M. Cut-off Throttle
80-40-F

Locomotive
Type 2-8-0
Class H6b
Number 2860

Subject: Coal Fired at Various Rates, High Rate — Altoona, Pa., 9-9-08




M. P. EXPERIMENTAL D-1
PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST No. 1299
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
R. P. M. CUT-OFF THROTTLE
80-40-F
SUBJECT: COAL FIRED AT VARIOUS RATES, LOW RATE
ALTOONA, PA., 9-10-08
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
EUREKA No. 6 COAL
2500 LBS. OF COAL PER HOUR
LENGTH OF TEST—MINUTES AND HOURS


M. P. Experimental D-1
LOCOMOTIVE
TYPE 2-8-0
CLASS H6B
NUMBER 2860
PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT
GRAPHICAL LOG OF LOCOMOTIVE TEST
TEST NO. 1200.1
R.P.M. CUT-OFF THROTTLE
80-40-F
SUBJECT: COAL FIRED AT VARIOUS RATES, LOW RATE
ALTOONA, PA., 9-10-08
BOILER PRESSURE, LBS. PER SQ. IN.
REVOLUTIONS PER MINUTE
DRAWBAR PULL, POUNDS
COAL POUNDS
FEED WATER POUNDS
BOILER PRESSURE
REVOLUTIONS
DRAWBAR PULL
WATER
COAL
2750 LBS. OF COAL PER HOUR
EUREKA NO. 6 COAL
LENGTH OF TEST—MINUTES AND HOURS

less amount of coal. While not called for in the schedule of tests to be made in connection with Circular 81 tests, a series of such tests have been included here as of particular interest in connection with economy in the use of fuel.

59. In all, four tests were made. Test No. 1297 represents the normal rate of firing. Coal for this test was fired uniformly at the rate of 3000 pounds of coal per hour, or 6000 pounds for the two hours of the test. The boiler pressure was good, averaging 203 pounds for the two hours. The drawbar pull and speed were very uniform. This test was carefully fired, and in the opinion of the fireman just enough coal was used and none wasted.

60. Next, the same test conditions were repeated, but coal was fired at a higher rate than before. Instead of 3000 pounds per hour, the rate was increased to 3500 pounds per hour, or 7000 pounds in two hours, an increase of 16.6 per cent. As would be expected, the surplus steam produced by this heavy firing escaped at the safety valve. In the test No. 1297, using 3000 pounds per hour, or the normal rate, the safety valve blew off 21 pounds of steam in two hours, while for the test firing 3500 pounds per hour, No. 1298, the valve blew off 1794 pounds in the two hours. This is a clear waste of steam and of coal needed to produce it. In the test under normal conditions, one pound of dry coal evaporated (equivalent evaporation) 9.20 pounds of water. The 500 additional pounds of coal should have evaporated 9.20x500 or 4600 pounds of water, but did actually evaporate but 39 per cent. of this. The steam lost through the safety valve seems, then, to be doubly wasteful, as it has been produced by means of a very poor evaporation, or by a large expenditure of coal for the result obtained.

61. The next test repeated the same running conditions but with the coal restricted, so that the fireman was allowed but 2500 pounds per hour, or 500 pounds less than he considered sufficient. This resulted in a low average boiler pressure for the test, namely 187.6 pounds, the pressure falling, in one hour, from 202 to 156 pounds. This is evidently much less coal than will sustain the demands upon the boiler, however carefully it is used.

62. Next, a test was made, still under the same running conditions, but with only 250 pounds less coal per hour than the normal rate. While the pressure was maintained for 50 minutes, it is evident that this quantity of coal is insufficient for this speed and cut-off. No trial was made using a quantity closer to the

3000 pounds per hour than 250 pounds, but it is probable that not even a reduction of 100 pounds per hour could be made; 250 pounds would be about 12 shovelfuls at 20 pounds per shovelful, and 100 pounds not quite six shovelfuls per hour. Then, if the fireman increases his rate of firing by six or seven shovelfuls per hour, coal is wasted, and if he reduces the rate by the same amount, the steam pressure will fall. Good firing, then, under Testing Plant conditions, means that coal is fired with an error of less than 100 in 3000, or the locomotive performance may be measured, as far as the coal consumption is concerned, with probable errors of less than 3 per cent.

63. The best practical rule to follow in road service is to carry a level fire as light as conditions will permit. Then, if steam pressure is maintained and the safety valve not allowed to blow, the best results in coal consumption will result.

TEST DEPARTMENT,

ALTOONA, PA.,

February 15, 1909.

PENNSYLVANIA RAILROAD COMPANY

LOCOMOTIVE TESTING PLANT

AT

ALTOONA, PENNA.

BULLETIN No. 23

PISTON VALVE DIAMETER

AND

VALVE STEM STRESS

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1914

LOCOMOTIVE TESTING PLANT.

PISTON VALVE DIAMETER AND VALVE STEM STRESS.

Conclusions on pages 31 and 66.

A Series of Valve Trials which has Aided in the Selection of a 12-Inch Piston Valve as a Suitable Standard Size to be used for Road Locomotives.

PART I.

VALVE DIAMETER.

INTRODUCTION.

1. The rigid adherence to a rule that the valve diameter should have a direct relation to the diameter or volume of the locomotive cylinder has resulted in the use of many valve diameters and a much larger number than appears to be warranted by the small differences in cylinder size.

2. With a view of checking this growing evil of valve sizes where they now range from 12 to 16 inches, and for the purpose of making a very desirable reduction in the weight of the valve itself, trials of valves made on the test plant have demonstrated that an arbitrary valve diameter of 12 inches is suitable for all of the recent classes of road locomotives where the cylinder diameter is more than 20 inches.

3. These trials have covered the use of valves of 16, 12 and 11 inches diameter on the K2sa class locomotive with a 24-inch diameter cylinder, valves of 14, 10 and 7 inches diameter on the E3sd class with a 22-inch cylinder, and valves of 14 and 12 inches diameter on the H8sb locomotive with cylinders 25 inches in diameter.

4. The piston valves that have been used on our locomotives are of two general types. The American Balance Valve Co.'s semi-plug valve, as shown in Fig. 1, has been in use on our locomotives ever since piston valves were introduced. It has been superseded, however, by the L ring type of valve as shown in Fig. 2.

These valve tests were undertaken to determine the effect upon the steam consumption, back pressure and the horsepower by a change in the diameter of valve, and valves of sizes not in ordinary use were made up for the tests. The odd size valves which were tested were not necessarily of a suitable form for general use, and a carefully worked-out design of 12-inch valve was prepared as shown in Figs. 1 and 22.

5. The following table gives information in regard to the valves for each of the locomotives with which valve tests were made:

Locomotive			Type of Valve	Diameter of Valve, Inches	Port Area, Square Inches	Weight of Valve, Pounds	Cylinder Diameter, Inches	Diameter of Valve Stem, Inches
No.	Class	Type						
877	K2sa	Pacific	American	16	63.91	263	24	2
"	"	"	L Ring Type	16	63.91	244	24	2
"	"	"	" " "	12	58.47	120	24	2
"	"	"	" " "	11	49.92	....	24	2
318	E3sd	Atlantic	American	14	74.23	218	22	2
"	"	"	L Ring Type	10	54.62	120	22	2
"	"	"	" " "	7	36.29	76	22	2
387	H8sb	Consolidation	American	14	74.04	224	25	2
"	"	"	L Ring Type	12	64.11	136	25	2

6. The valves were of two types, the American Semi-Plug and the L ring. The general form of the American valve and a section of its ring are shown in Figs. 1 and 18, while the general form of the L ring valve is shown in Figs. 2 and 3. A further description of valves of these two types is given in Bulletin No. 7, "Piston Valves."

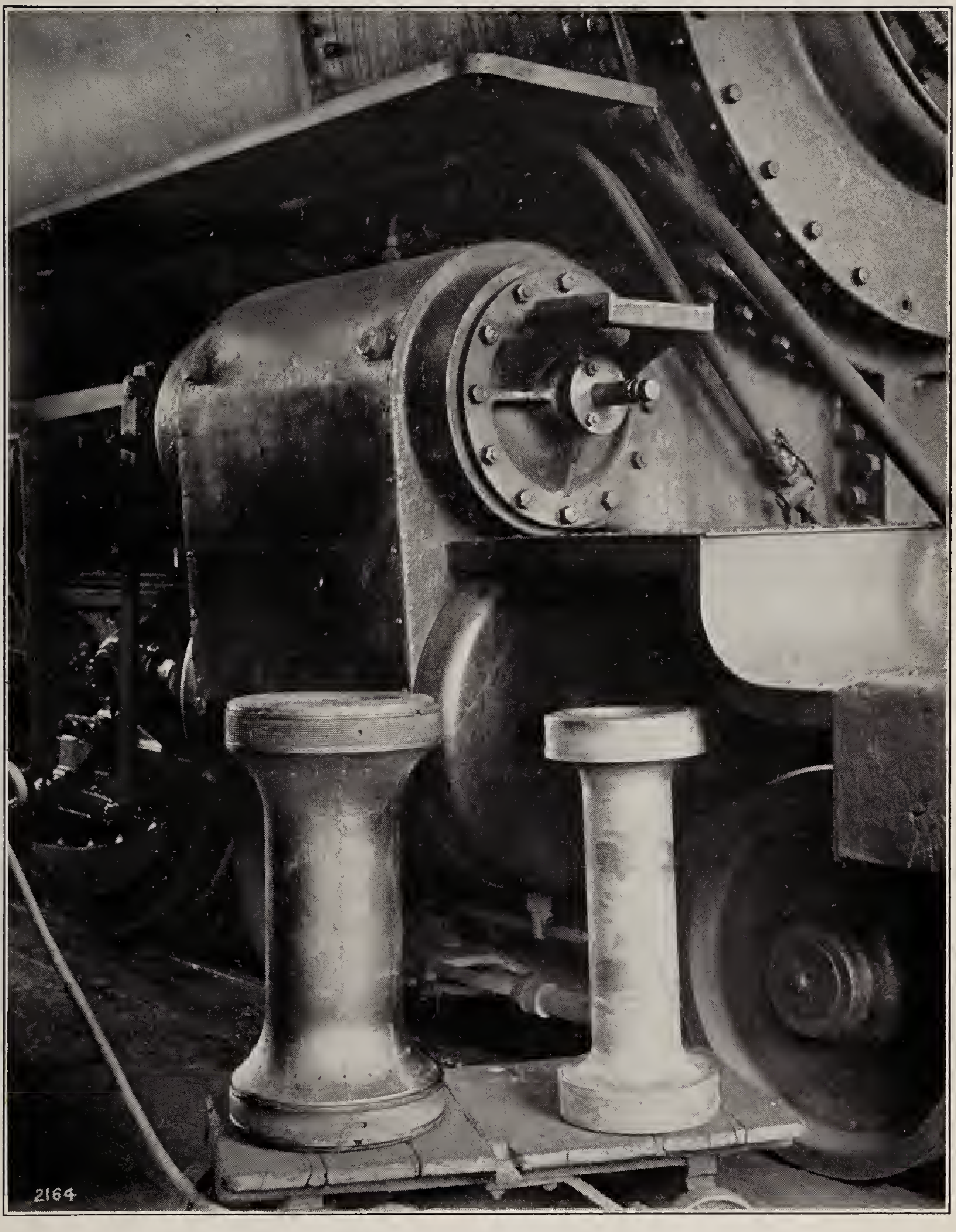


Fig. 1.

THE K2 LOCOMOTIVE AND ITS VALVES.

The 16-inch American Balance Valve Co. semi-plug piston valve and the new form of 12-inch valve with L type rings. The 12-inch valve is used to replace the 16-inch on the K2 locomotive as shown in this view. The large valve weighs 263 pounds and the small valve 120 pounds.

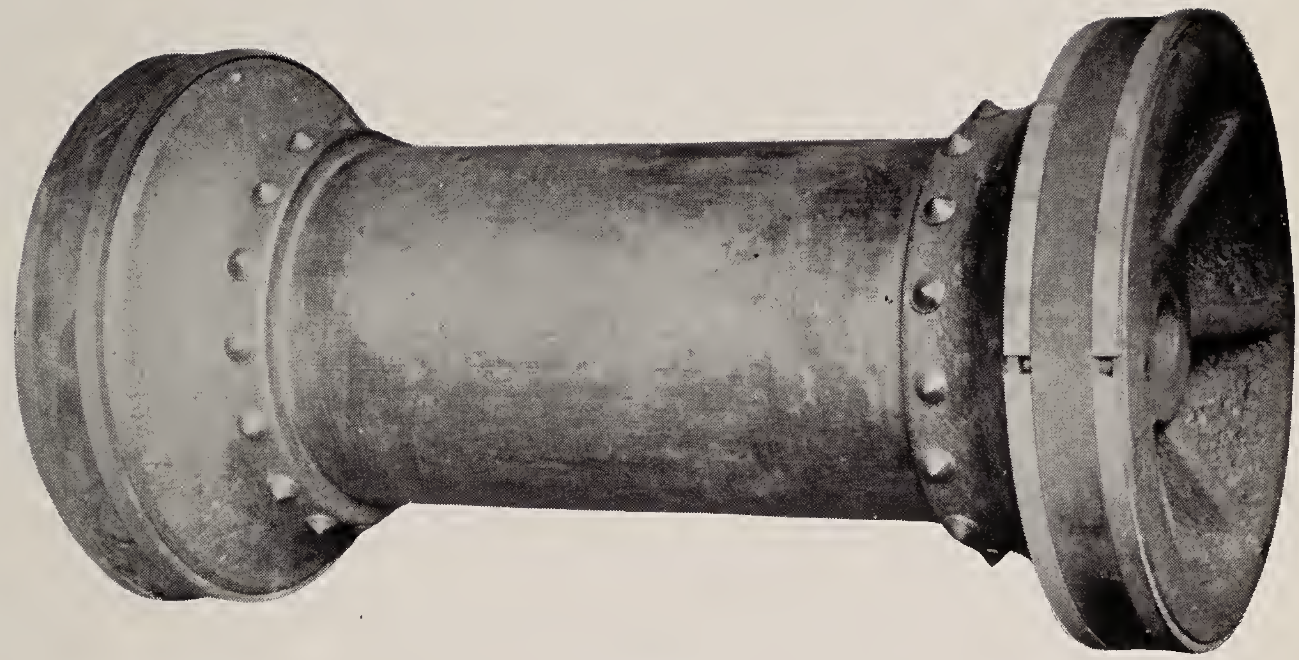


Fig. 2.

VALVE FOR THE K2 LOCOMOTIVE.

The 16-inch valve of the L ring type weighing 244 pounds.

Locomotives Used for Valve Tests.

7. The locomotives used for these tests were No. 877, class K2sa, a simple Pacific type locomotive, No. 318, class E3sd, a simple Atlantic type locomotive, and No. 387, class H8sb, a simple Consolidation type locomotive. These locomotives have superheaters and are representative of the road locomotives used at the present time in the passenger and freight service on this railroad.

Class K2sa Locomotive.

8. We will consider first the valve tests with the K2sa Pacific type locomotive No. 877. This locomotive is described in Bulletin No. 18, where the tests with 16-inch valves are given in detail. The valves used were of three sizes, the regular 16-inch valve as shown in Figs. 2 and 3, a 12-inch valve as shown at A in Fig. 22 and a specially designed valve of 11 inches diameter as shown in Fig. 4. The American valve was not tried with this locomotive.

9. There are plotted in Fig. 5 the steam consumption in pounds per indicated horsepower and the indicated horsepower developed when using each of the three valves previously mentioned.

10. It is observed that the steam consumption at similar indicated horsepowers is greatest when using the 12-inch valves. The steam consumption then amounts to 20 pounds per indicated horsepower when developing 1400 i.h.p. and 17.7 pounds per indicated horsepower when 2400 i.h.p. is reached. With the 16-inch valves the steam per i.h.p. hour is lower, ranging from 17.5 to 16.3 pounds through the same limits of power developed by the locomotive. The locomotive when equipped with the 11-inch valves shows a still greater economy, for at 1400 i.h.p. the steam consumption is 16.3 pounds per i.h.p. hour, and at 2200 i.h.p. it amounts to approximately 15.3 pounds. The maximum horsepower is the same with the 16- and 11-inch valves.

11. Referring to Fig. 6, which presents in a like manner the relation between the total steam consumption per hour and the indicated horsepower developed by this locomotive when equipped with each of these different size valves, the same inconsistency is apparent.

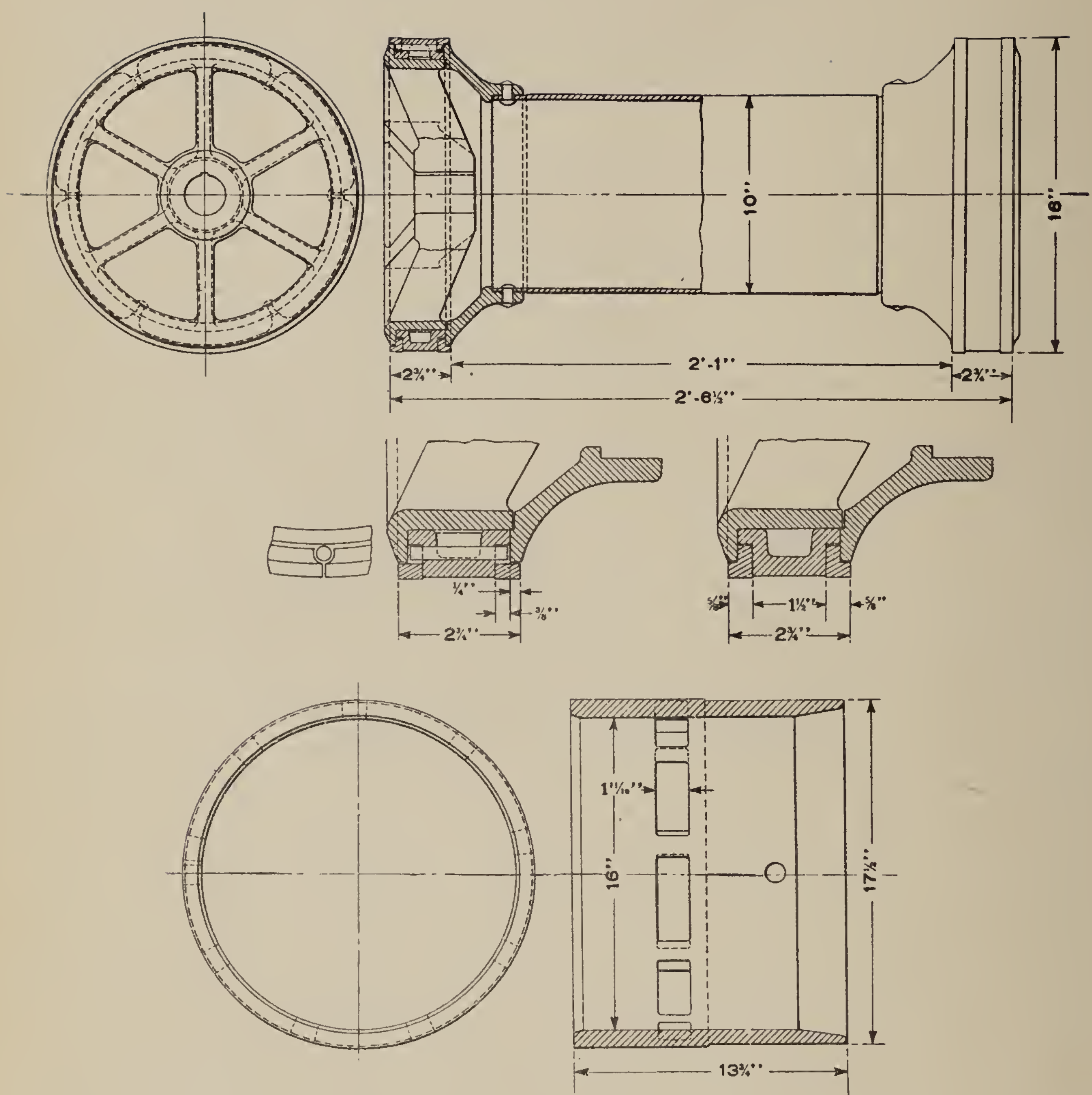


Fig. 3.

PISTON VALVE AND VALVE CAGE—K2sa LOCOMOTIVE.

The 16-inch valve of the L ring type.

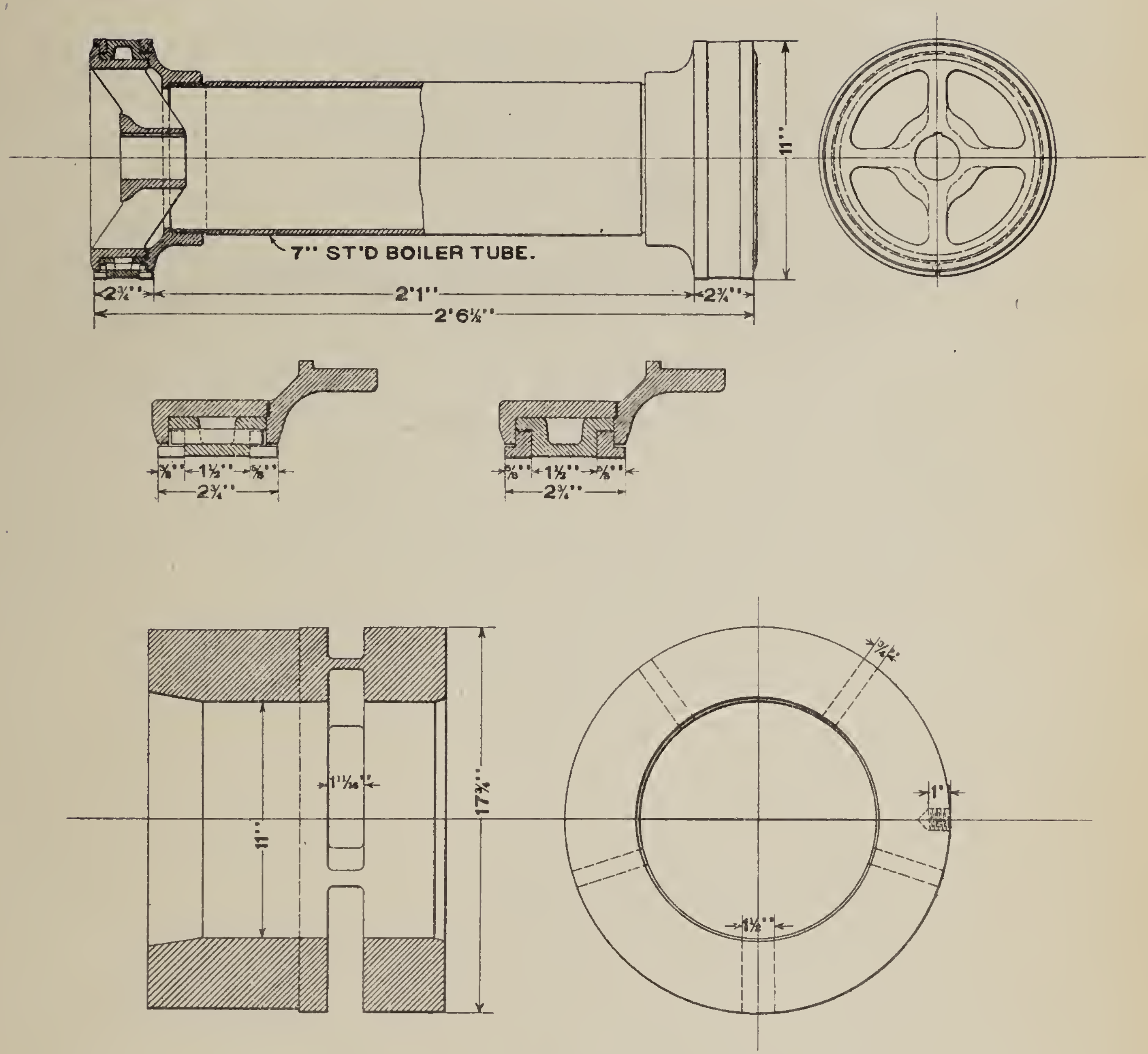


Fig. 4.

VALVE AND VALVE CAGE—CLASS K2sa LOCOMOTIVE.

The 11-inch valve with L type rings.

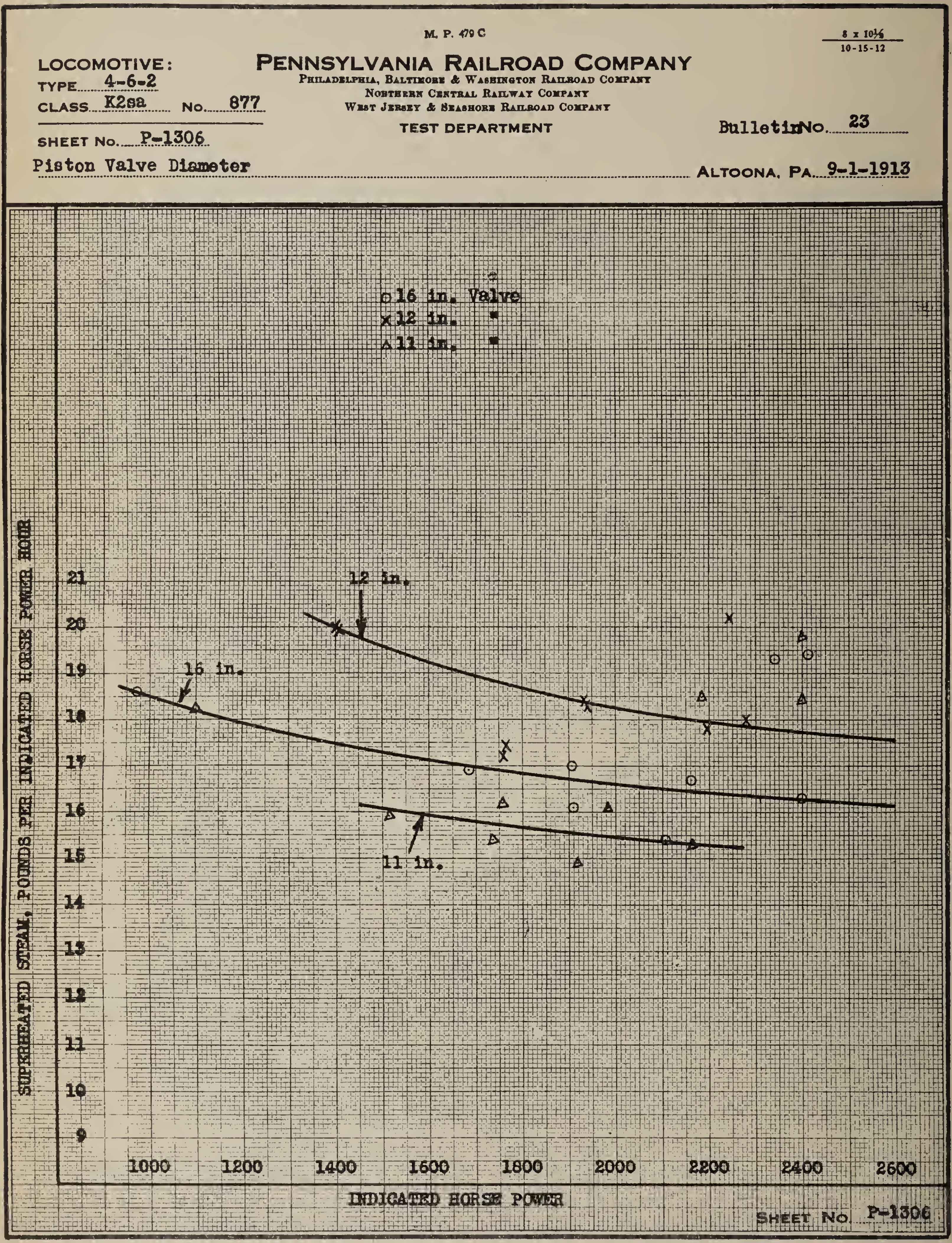


Fig. 5.

STEAM PER INDICATED HORSEPOWER—K2sa LOCOMOTIVE.

The indicated horsepower and steam per horsepower with valves 16, 12 and 11 inches in diameter. The 12-inch valve in this case shows the highest water rate, but the smallest valve, the 11-inch, shows the lowest rate.

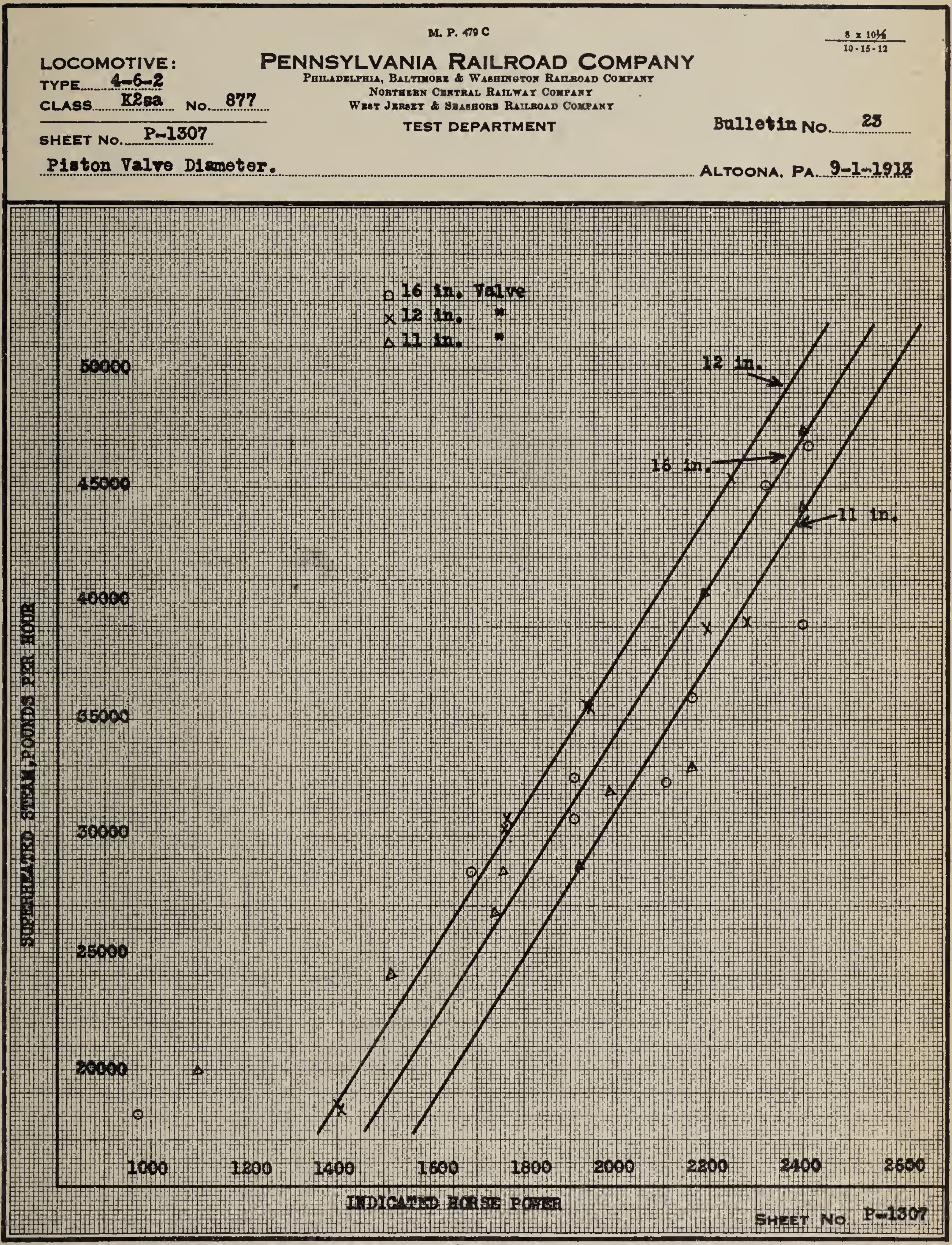


Fig. 6.

STEAM AND HORSEPOWER—K2sa LOCOMOTIVE.

The total steam and indicated horsepower for the three valves.

12. There is a greater steam consumption with the 12-inch valves than with the 16-inch valves, and the locomotive when fitted with 11-inch valves shows a greater economy in water than when it is equipped with either the 12-inch or 16-inch valves throughout the whole range of power output.

13. The least back pressure in pounds per square inch is plotted with the indicated horsepower in Fig. 7. The single curve drawn through the points plotted for each of the three valves indicates that the least back pressure is the same on this locomotive regardless of whether it is fitted with valves whose diameters are 16 inches, 12 inches or 11 inches.

14. The least back pressure increases from 2.4 pounds at 1400 i.h.p. to 15 pounds at 2400 i.h.p. as shown by the curve. That the 12-inch valve does not limit the horsepower has been demonstrated by tests, in another series, where this locomotive, with 12-inch valves, developed 2489.5 i.h.p. at 240 r.p.m. or 56 m.p.h. and with a cut-off of 50 per cent.

Class E3sd Locomotive.

15. The Atlantic type locomotive, class E3sd, using superheated steam and ordinarily equipped with 14-inch valves, had its valve chambers bushed first for 10-inch valves and then for 7-inch valves.

16. The 14-inch valve is shown in Fig. 8, the 10-inch valve in Fig. 9 and the 7-inch valve in Fig. 10. All of these valves are of the L ring type.

17. The steam consumption per indicated horsepower hour is approximately the same for this locomotive when it is equipped with any one of these three valves. The steam consumption ranges between 19 pounds per i.h.p. at 900 i.h.p. and 18.3 pounds per i.h.p. at 1950 i.h.p. as indicated by the curve in Fig. 11.

18. It is likewise shown in Fig. 12 that the total steam consumption per hour is the same for like indicated horsepowers regardless of which of the three valves is applied to this locomotive.

19. The least back pressure in pounds per square inch is plotted with the indicated horsepower in Fig. 13, and it is observed that the least back pressure for the 7-inch valve is greater than that for the larger 14-inch valve, while the 10-inch valve has a least back pressure less than that of either the 14-inch or 7-inch valves at like horsepowers.

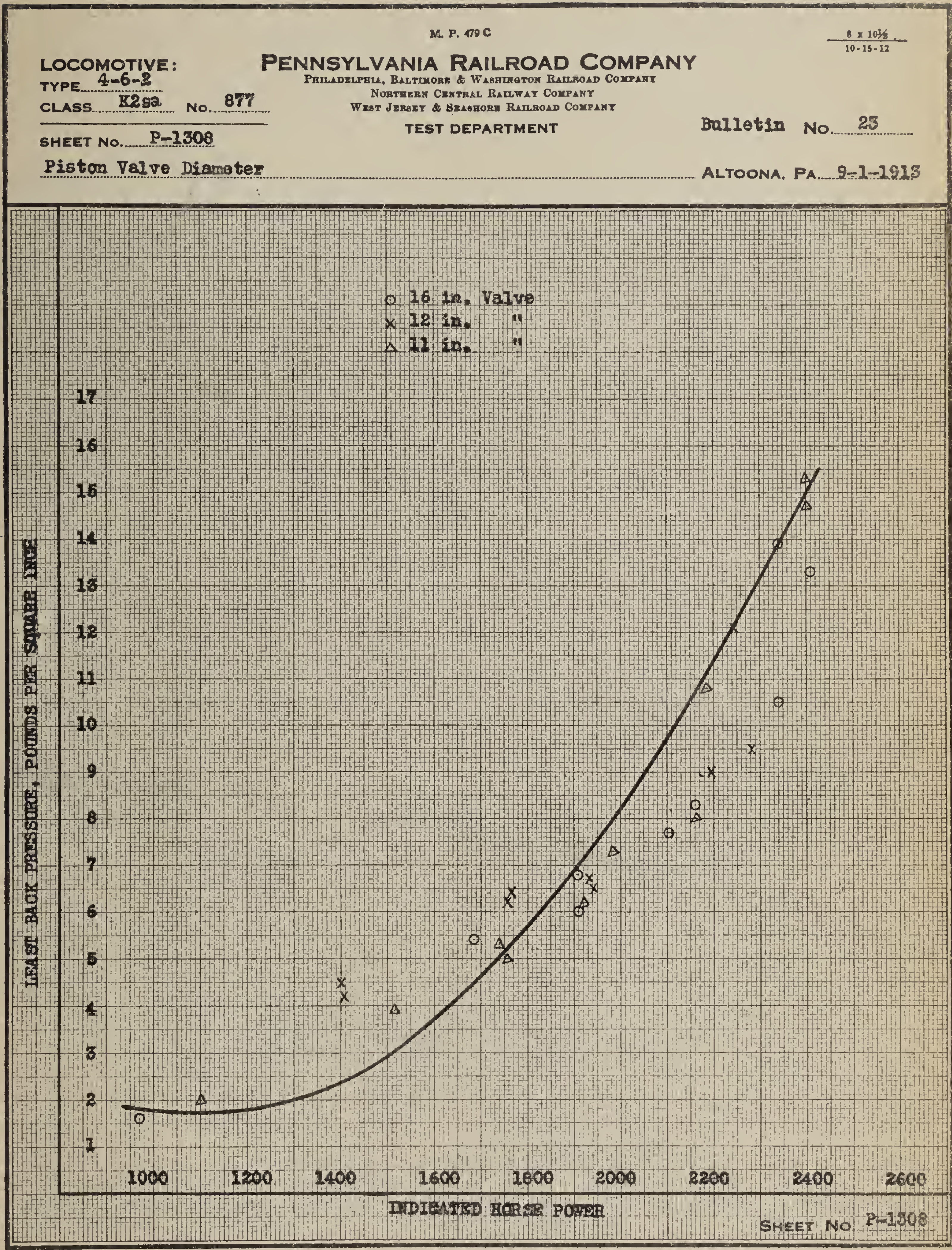
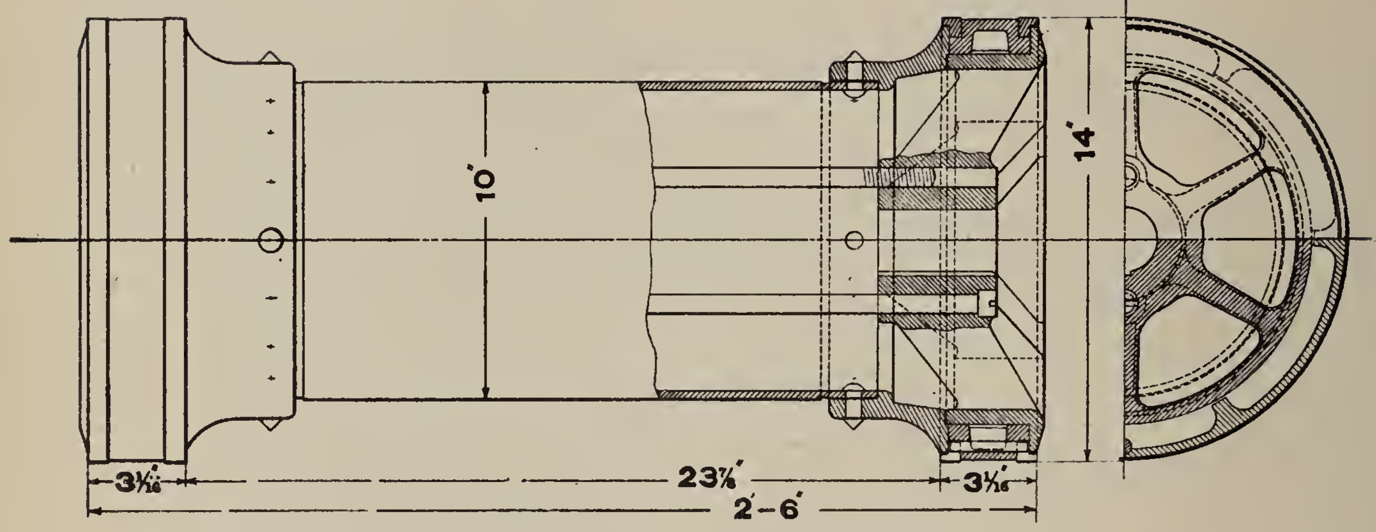


Fig. 7.

INDICATED HORSEPOWER AND BACK PRESSURE—K2sa LOCOMOTIVE.

There is little difference in the back pressure with the different valves.



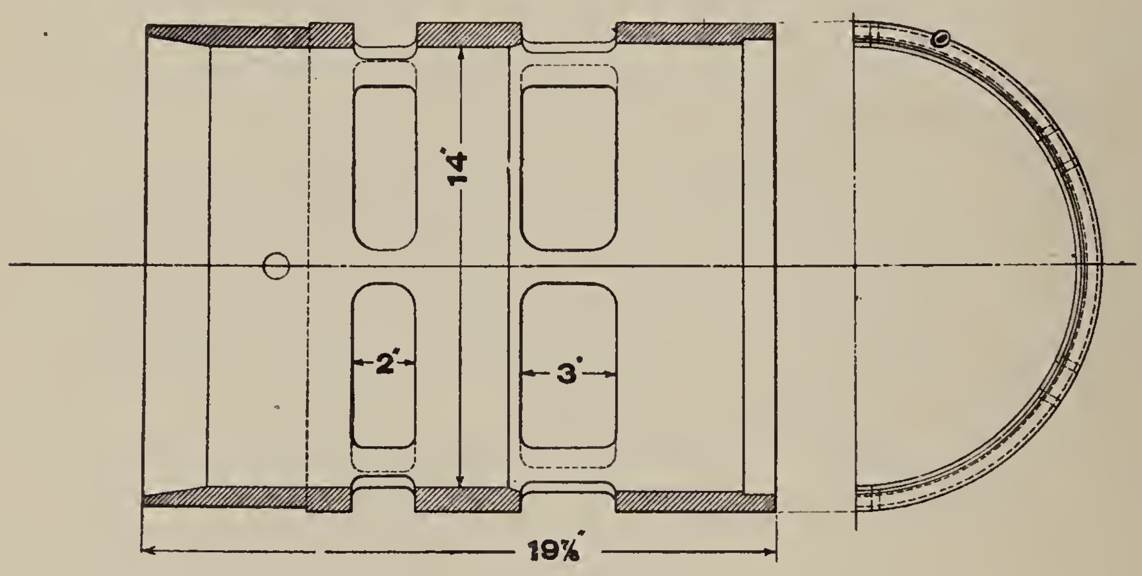


Fig. 8.

VALVE AND VALVE CAGE—CLASS E3sd LOCOMOTIVE.
The 14-inch valve which was standard for this locomotive.

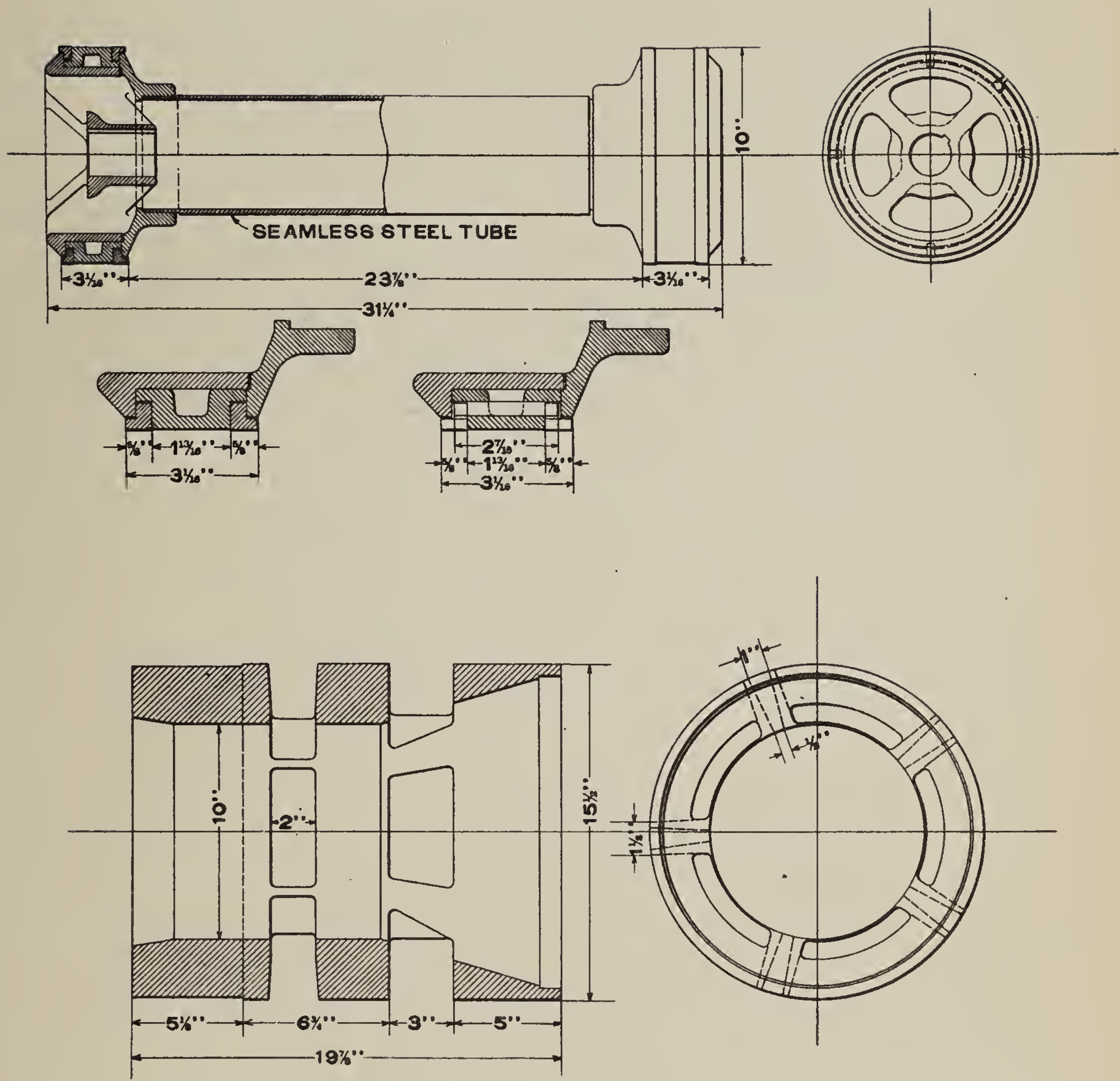


Fig. 9.
VALVE AND VALVE CAGE—CLASS E3sd LOCOMOTIVE.
The 10-inch valve.

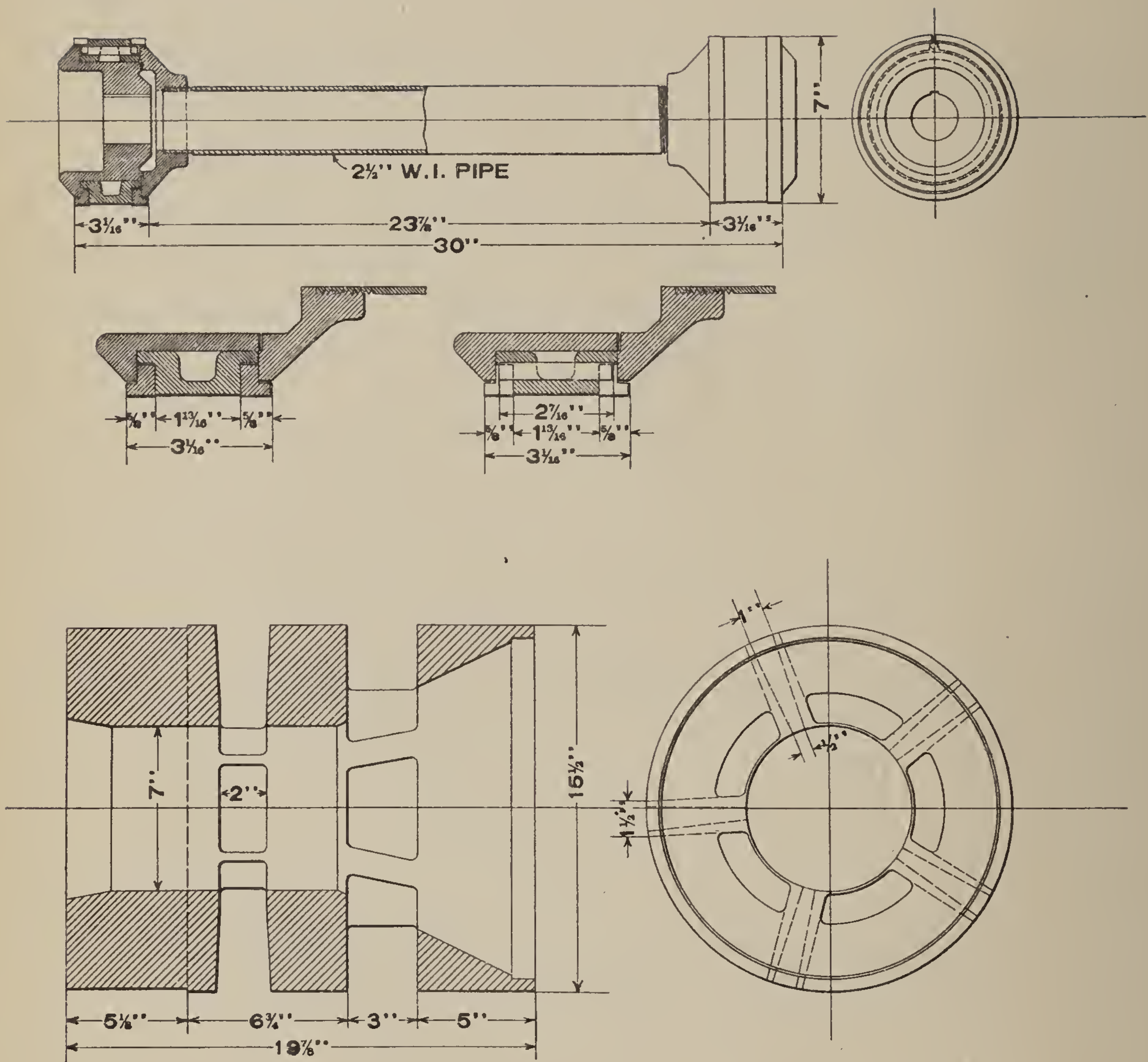


Fig. 10.

VALVE AND VALVE CAGE—CLASS E3sd LOCOMOTIVE.

This was the smallest valve tried, 7 inches in diameter. The valve cage had to be made very thick.

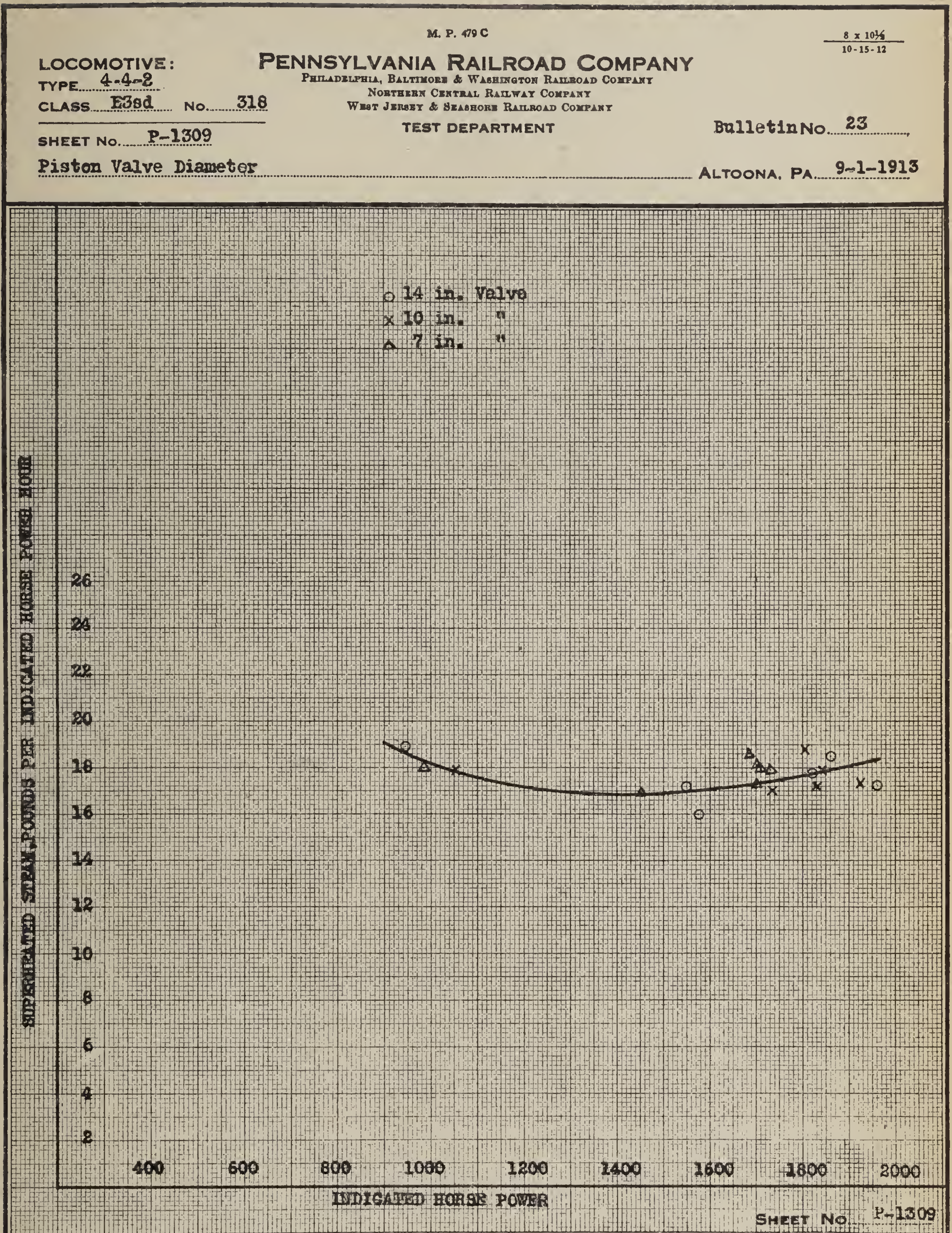


Fig. 11.

STEAM PER HORSEPOWER—CLASS E3sd LOCOMOTIVE.

No distinction can be made between the different sizes of valves.

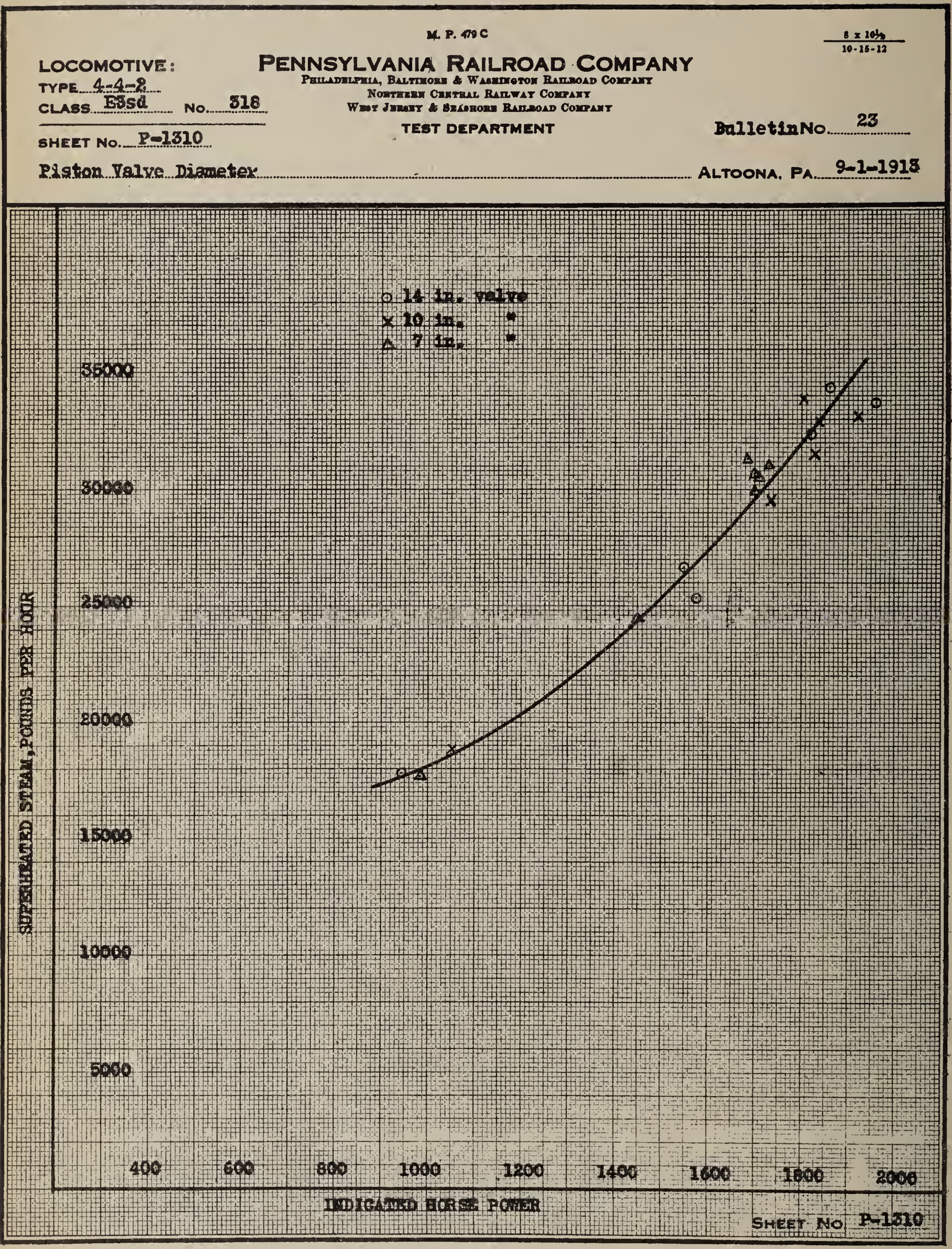


Fig. 12.

STEAM AND HORSEPOWER—CLASS E3sd LOCOMOTIVE.

The total steam and indicated horsepower for three valves.

M. P. 479 C

8 x 10½
11-20-13

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

SHEET No. P-1311

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 23

Piston Valve Diameter

ALTOONA, PA. 9-1-1913

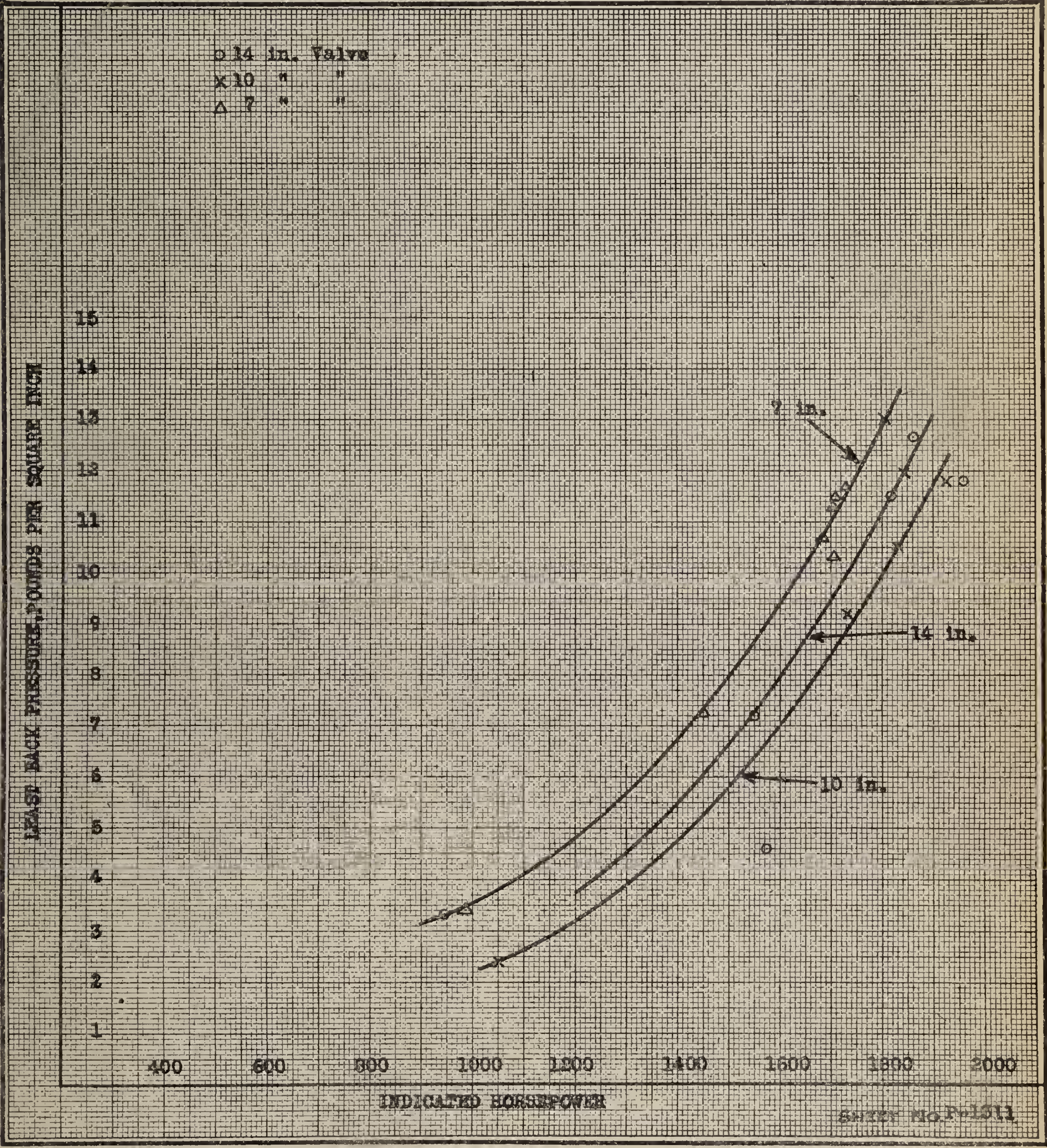


Fig. 13.

INDICATED HORSEPOWER AND BACK PRESSURE—E3sd LOCOMOTIVE.

There is little difference in the back pressure with the different valves.

20. Comparing the curves representing the performance of the K2sa and the E3sd locomotives, it is noted that in the case of the K2sa locomotive, where the steam consumption varies with the size of the valve, the least back pressure is constant regardless of the valve diameter, while with the E3sd locomotive just the reverse is true. Thus, it would appear that the question of valve diameter does not enter when considering the steam economy of a locomotive. The inconsistencies of the curves cannot fail to attract attention.

Typical Indicator Diagrams for E3sd Locomotive.

21. Typical indicator diagrams representative of the cylinder performance of this locomotive when equipped with 7-inch valves are given on Figs. 14 and 15. Indicator cards are similarly shown in Figs. 16 and 17 for this locomotive when equipped with the 10-inch valves.

22. With each diagram are given the test number, the scale of pressure, whether taken from the right or left side or from the head or crank end of the cylinder, and below the diagram are given the speed in revolutions per minute and miles per hour, the nominal cut-off and the indicated horsepower. The steam-chest diagram is given for cards taken from the left side of the locomotive.

Class H8sb Locomotive.

23. A series of tests was made on the H8sb consolidation type superheated steam locomotive equipped with 14-inch valves, and later a number of tests were made with the 12-inch valves.

24. The original 14-inch American semi-plug type valve used during these tests is shown on Fig. 18. The 12-inch L ring type of valve is shown at A in Fig. 22.

25. The tests were run at speeds ranging between 10.7 and 30.5 miles per hour with cut-offs between 20 and 50 per cent. of the stroke.

26. The steam consumption per indicated horsepower hour is plotted in Fig. 19 with the indicated horsepower developed by the locomotive when fitted with the 14-inch and 12-inch valves.

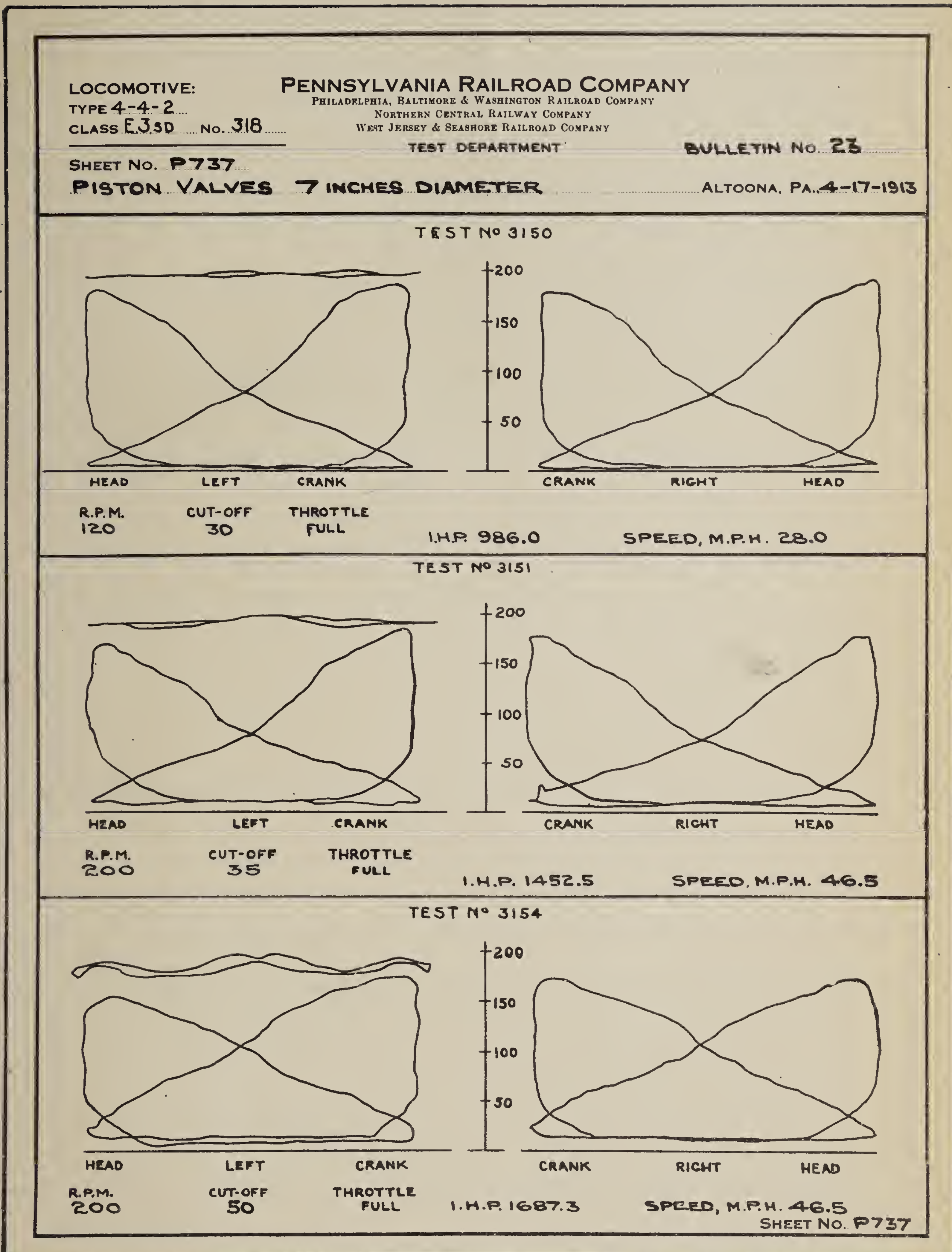


Fig. 14.

TYPICAL INDICATOR DIAGRAMS—CLASS E3sd LOCOMOTIVE.

These diagrams were made with the 7-inch valves.

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3 s D No. 318.

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

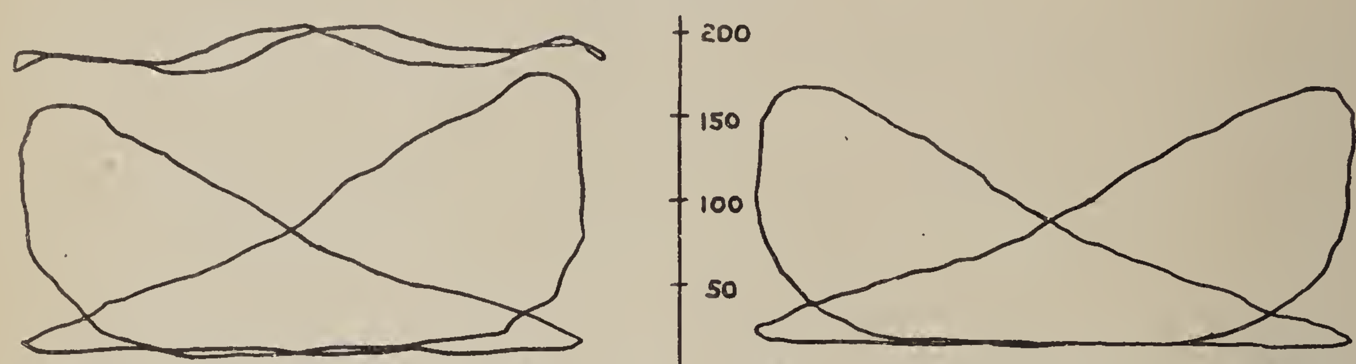
BULLETIN No. 23

SHEET No. P738

PISTON VALVES 7 INCHES DIAMETER

ALTOONA, PA., 4-17-1913

TEST No 3153



HEAD LEFT CRANK

HEAD RIGHT CRANK

R.P.M.	CUT-OFF	THROTTLE
240	40	FULL

I.H.P. 1702.9 SPEED, M.P.H. 55.8

SHEET No. P738

Fig. 15.

TYPICAL INDICATOR DIAGRAMS—CLASS E3sd LOCOMOTIVE.

These diagrams were made with the 7-inch valves.

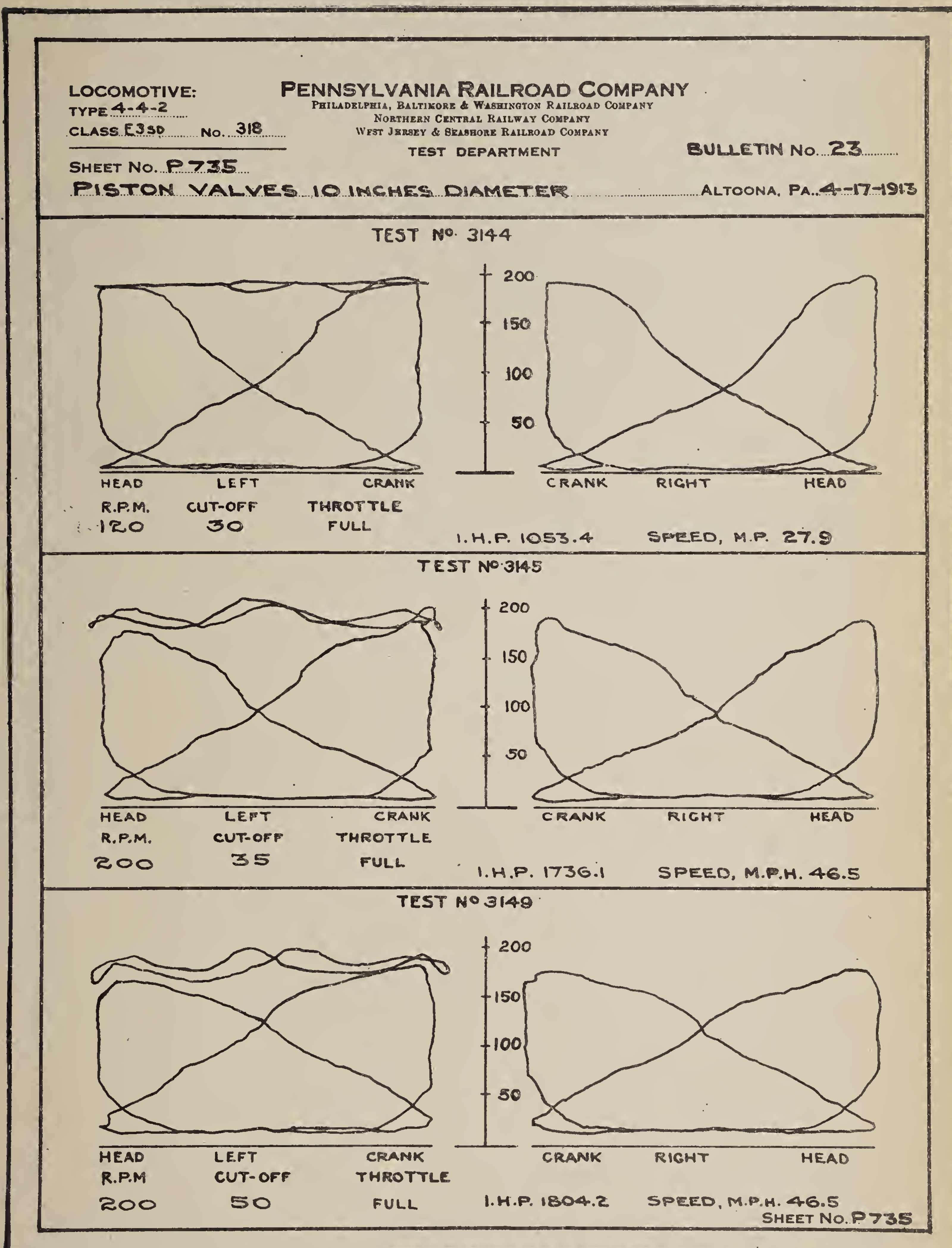


Fig. 16.

TYPICAL INDICATOR DIAGRAMS—CLASS E3sd LOCOMOTIVE.

These diagrams were made with the 10-inch valves.

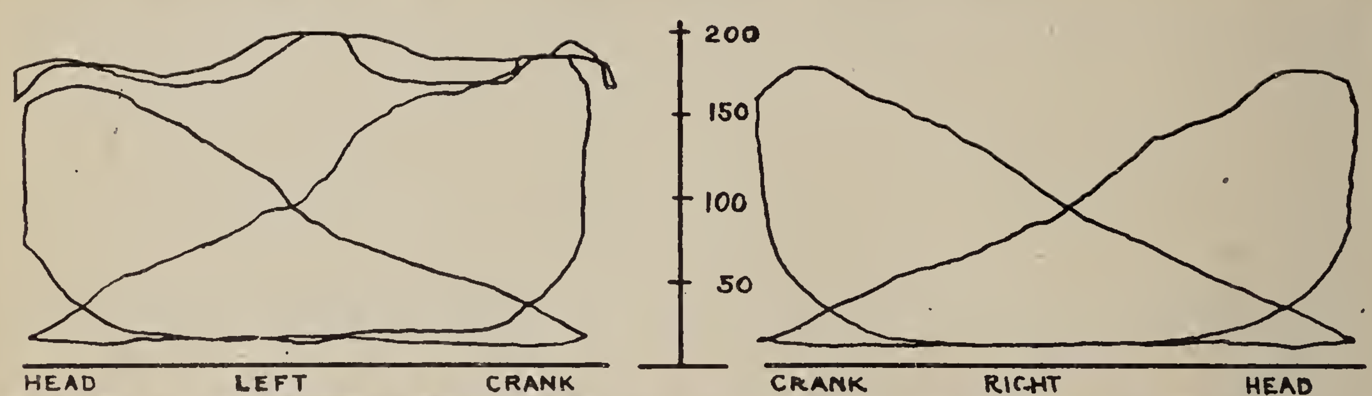
LOCOMOTIVE:
TYPE 4-4-2.
CLASS E3SD ... NO. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

BULLETIN NO. 23

SHEET NO. P736
PISTON VALVES 10 INCHES DIAMETER ... ALTOONA, PA. 4-17-1913

TEST Nº 3147



R.P.M.	CUT-OFF	THROTTLE		
240	40	FULL	I.H.P. 1922.9	SPEED, M.P.H. 55.8

SHEET NO. P736

Fig. 17.
TYPICAL INDICATOR DIAGRAMS—CLASS E3sd LOCOMOTIVE.
These diagrams were made with the 10-inch valves.

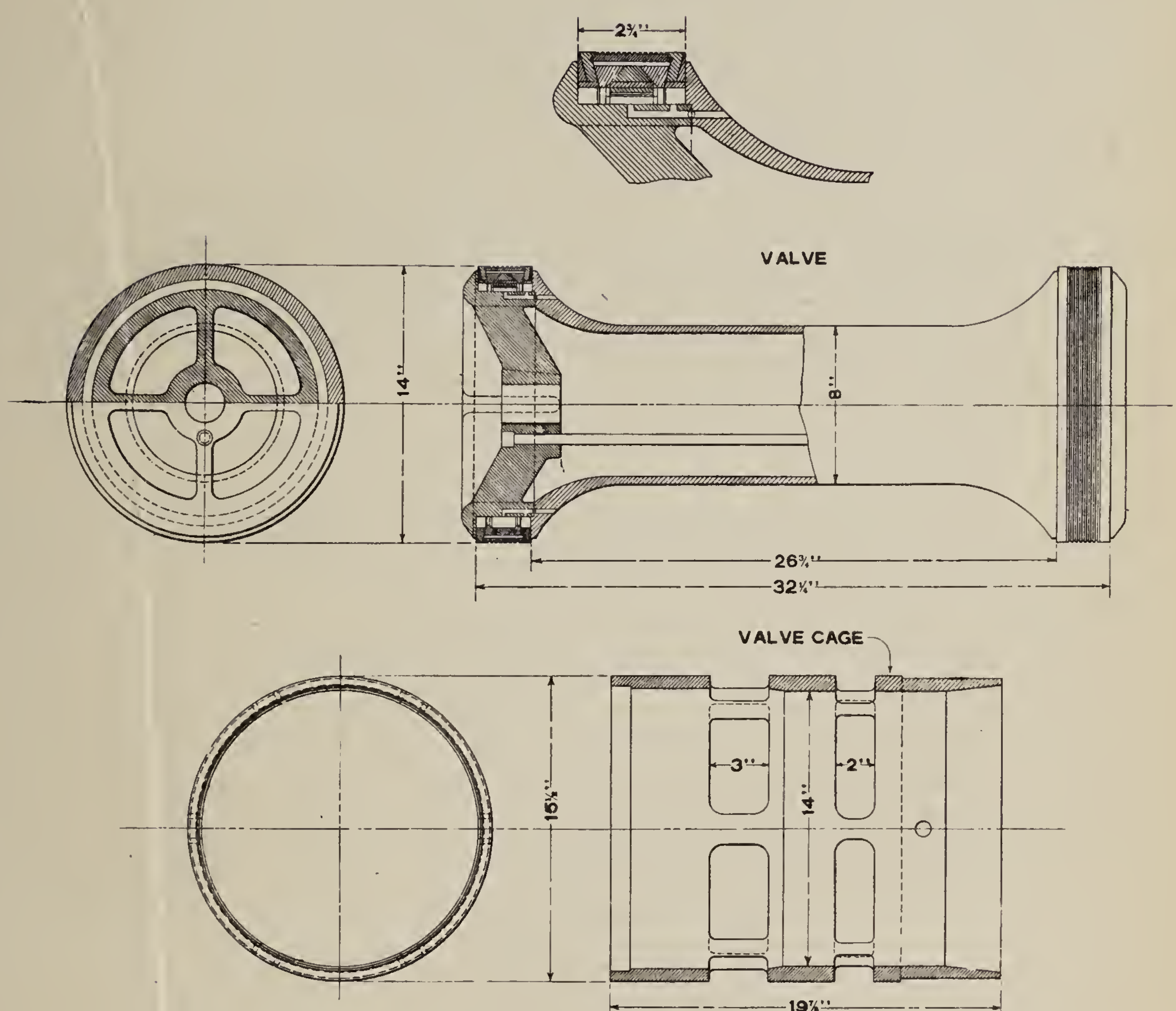


Fig. 18.

VALVE AND VALVE CAGE—CLASS H8sb LOCOMOTIVE.

This was the standard valve for this class of locomotive.

27. It is observed from the curves representing the performance of this locomotive that the steam consumption per i.h.p. hour is less for the 14-inch than for the 12-inch valves. The steam consumption for the 12-inch valves ranges between 23.1 and 18.6 pounds of steam per indicated horsepower hour when the power developed by the locomotive ranges between 600 and 1800 indicated horsepower. With the 14-inch valves the steam consumption ranges between 20.8 and 17.6 pounds of steam per indicated horsepower hour through the same range in the power developed by the locomotive. There is no appreciable loss in horsepower with the smaller valves.

28. It is similarly shown in Fig. 20 that when the locomotive is equipped with the smaller 12-inch valves the total steam consumption in pounds per hour is, at like indicated horsepowers, larger than the steam consumption obtained when using 14-inch valves.

29. Curves plotted in Fig. 21 with the least back pressure in pounds per square inch as ordinates and the indicated horsepower as abscissæ show that the least back pressure is less when using 14-inch valves than when the small 12-inch valves are used. As the power of the locomotive is increased from 600 to 1800 i.h.p. the least back pressure increases from 1.3 to 8.7 pounds when using 12-inch valves, while with the 14-inch valves the least back pressure increases from 0.8 to 7.9 pounds.

New 12-Inch Valve.

30. The form of the 12-inch valve used in the tests is shown at A in Fig. 22. It consists of a spool or central portion made up of a seamless steel tube, the tube being flanged at each end and the central part reduced in diameter to make it lighter in weight. The rings are of cast iron of an L section.

31. Since the tests were made the valve has been modified as shown at B in Fig. 22. The new valve, which is now standard, in two overall lengths, is suitable for all piston valve road

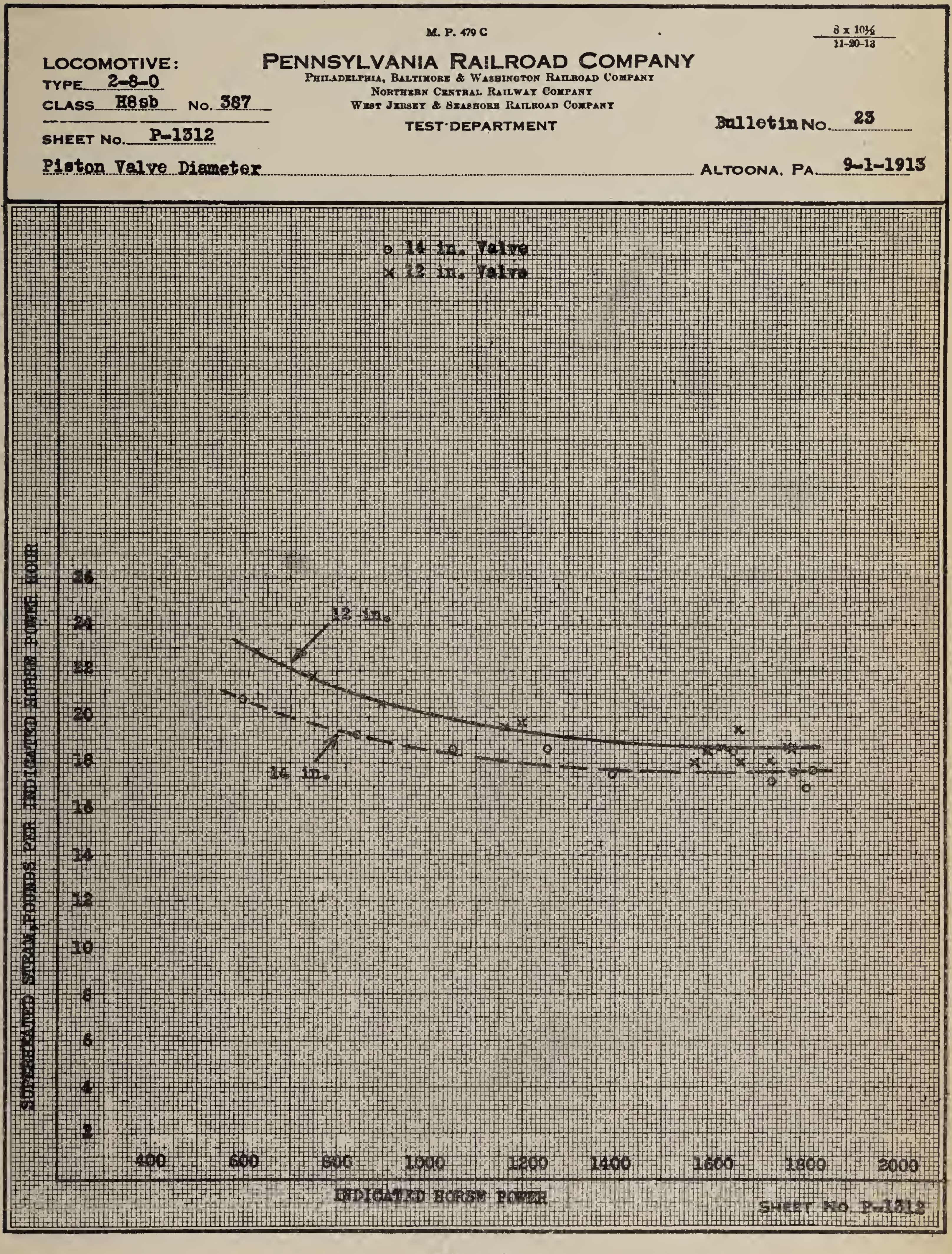


Fig. 19.

STEAM PER HORSEPOWER—CLASS H8sb LOCOMOTIVE.

In this case the 14-inch valve shows the lower steam consumption.

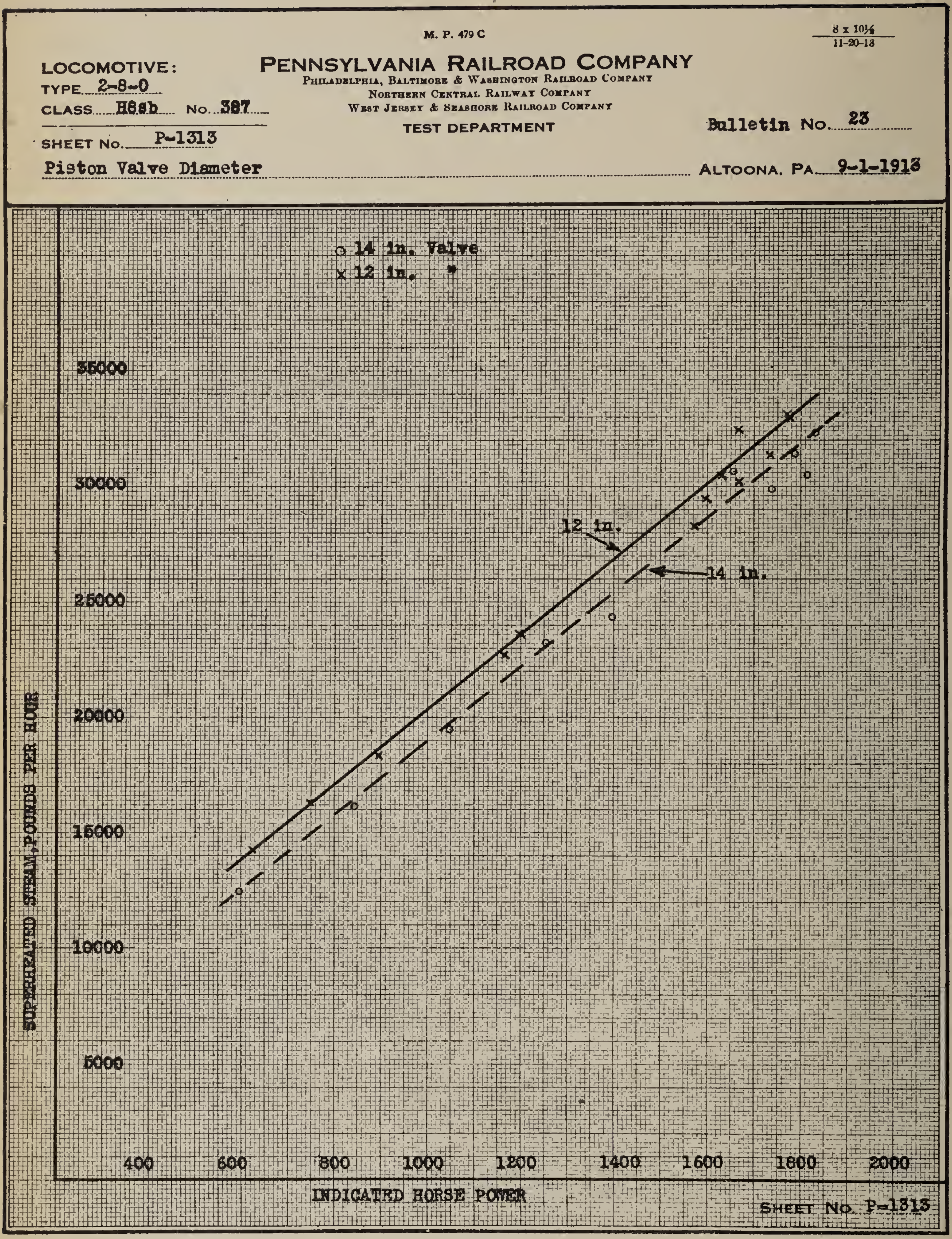


Fig. 20.

STEAM AND HORSEPOWER—H8sb LOCOMOTIVE.

The total steam and indicated horsepower for the two valves.

25" Cylinders

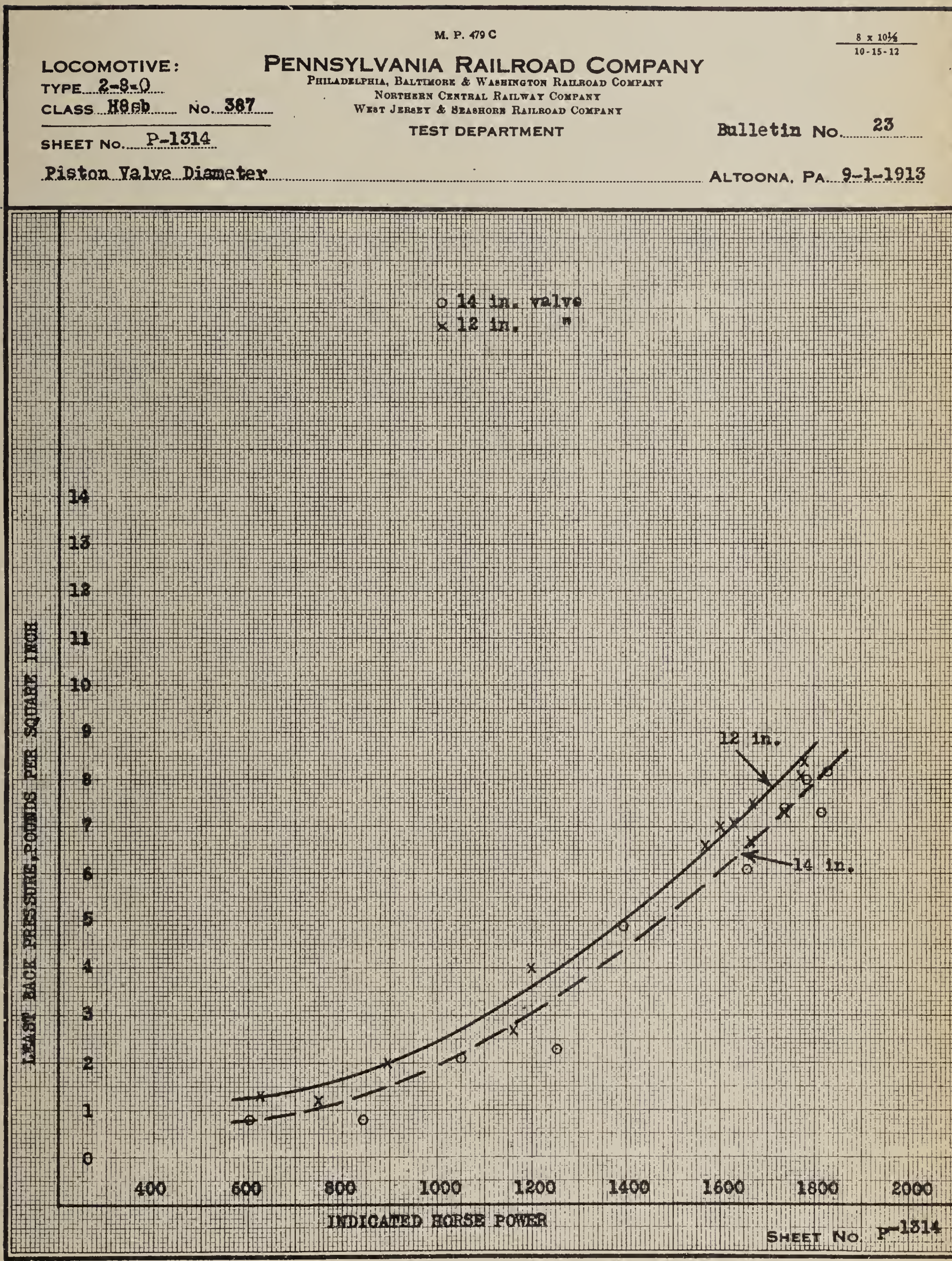


Fig. 21.

INDICATED HORSEPOWER AND BACK PRESSURE—H8sb LOCOMOTIVE.

There is little difference in the back pressure with the different valves.

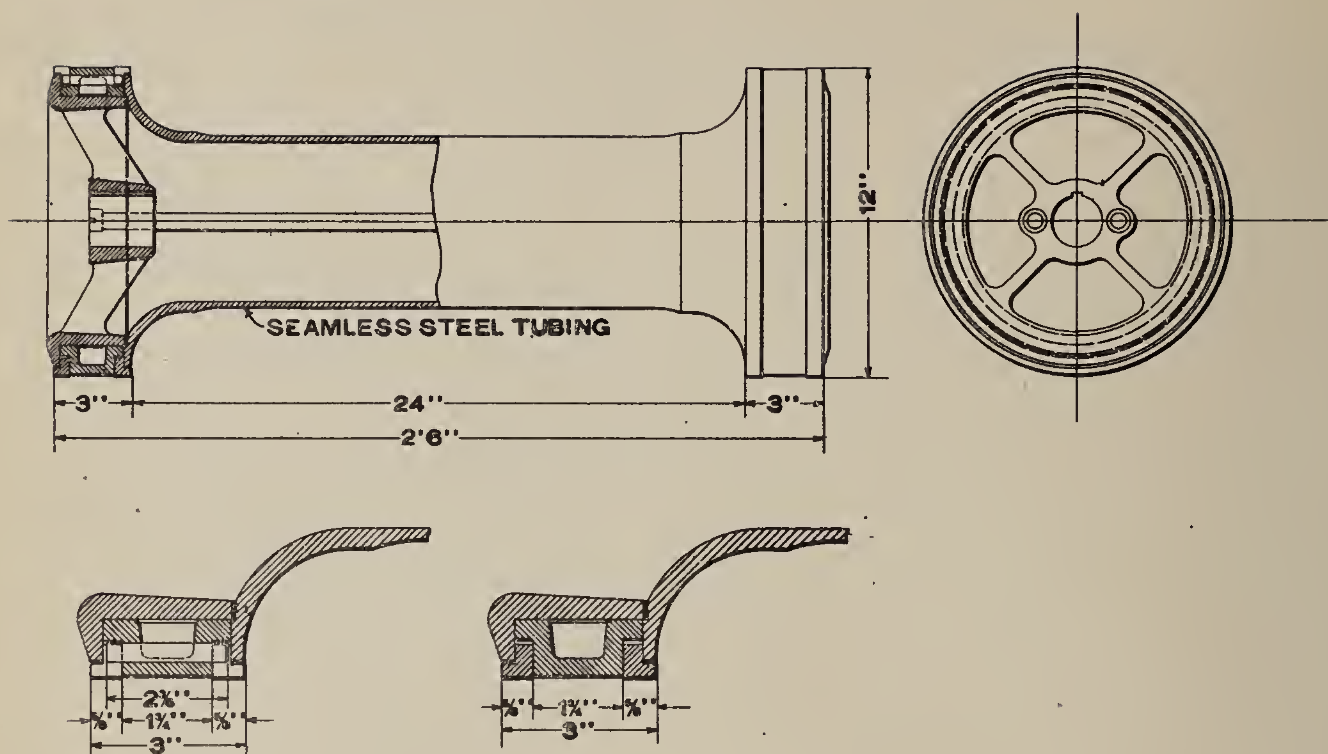


Fig. 22-A.
PISTON VALVE, 12 INCHES IN DIAMETER.
This is the general form of the light 12-inch valve with L type rings as used in the test. A photograph is shown in Fig. 1.

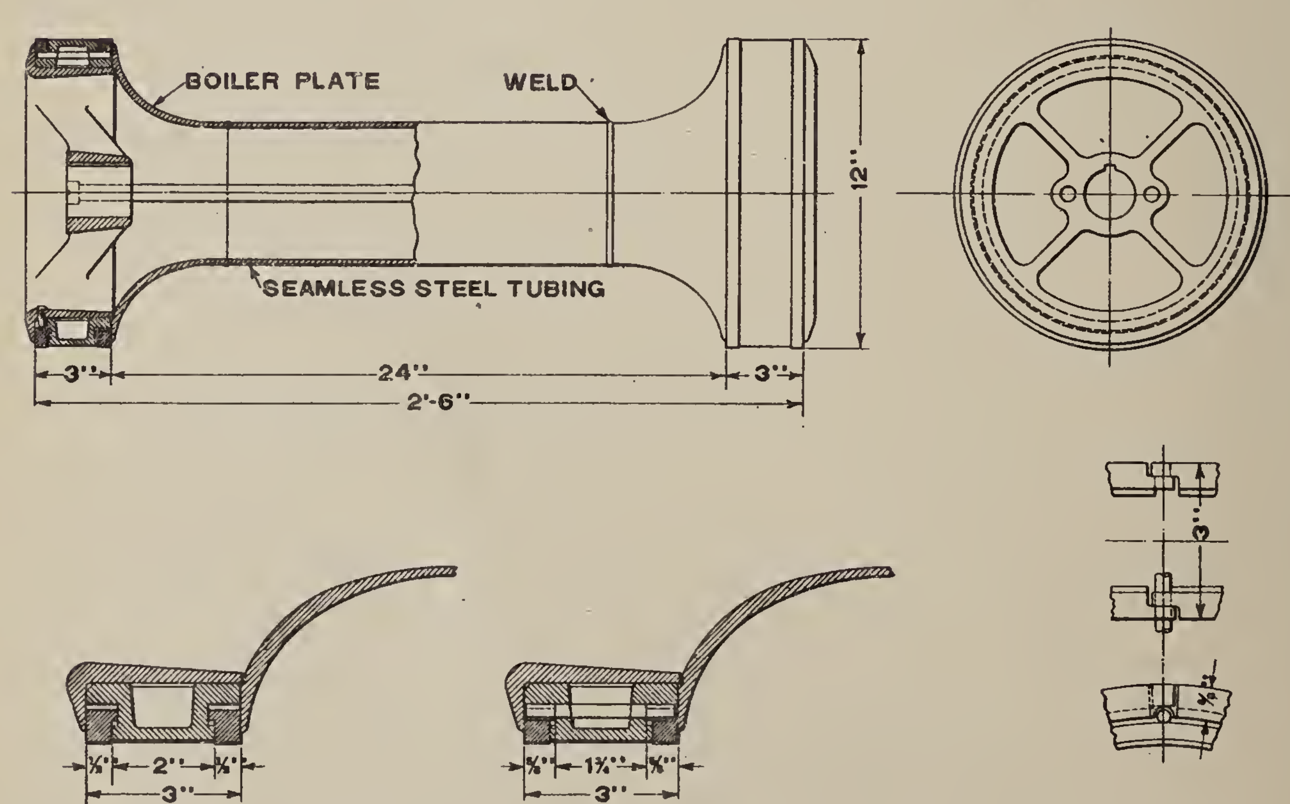


Fig. 22-B.
PISTON VALVE, 12 INCHES IN DIAMETER.
This is the present form of the light 12-inch valve, it has rings of the anchored L type.

locomotives. It consists of a spool or central portion, constructed from a piece of $5\frac{1}{2}$-inch seamless steel tubing, to each end of which is welded a piece of boiler plate flanged to a bell shape. The valve heads are of drop forged steel and each has four arms. The rings are of cast iron of the anchored L section, the ends being lapped past each other to prevent leakage. The rings are held apart by a cast iron spacer. The complete valve weighs approximately 120 pounds.

Method of Applying the 12-Inch Valve to Old Locomotives.

32. The application of the 12-inch piston valve necessitated the bushing of the valve chambers or steam chests, which were originally arranged for the larger valves. For this purpose, valve cages, one of which is shown in Fig. 23, were designed.

CONCLUSIONS.

Valve Diameter.

1. This series of tests has proven that differences in the size of the valve of a simple locomotive using superheated steam do not have any important effect upon the steam consumption or power.

2. The inconsistencies in the data obtained from tests of these locomotives of different types are so considerable that no other conclusion can be intelligently drawn.

3. It is also true that the condition of the valve has more effect upon the steam consumption of a locomotive than has the valve diameter. With the valves in first-class condition, it is possible that the steam consumption will be identically the same regardless of the size of the valve, within reasonable limits, as was shown in Figs. 11 and 12 of the performance of the E3sd locomotive using 14-inch, 10-inch and 7-inch valves. The smallest diameter valve should show less leakage of steam on account of its small circumference, but it does not do so in this case.

4. To establish a relation between the valve and cylinder so that the valve may be standardized, it may be stated generally that the diameter of the valve in inches for superheated steam should not be less than $0.016D^2$ where D = the diameter of cylinder in inches. The 12-inch valve is now used for cylinders between 20 and 27 inches in diameter, while for cylinders of 20 inches or less an 8-inch valve is used. Cylinders above 27 inches diameter have not been used for any class of locomotive of which there is more than one example, and a valve diameter for such cylinders need not be considered at present.

5. Decreasing the valve diameter on a locomotive necessitates increasing the percentage of cut-off to obtain the same power at the same speed. This causes a longer valve travel.

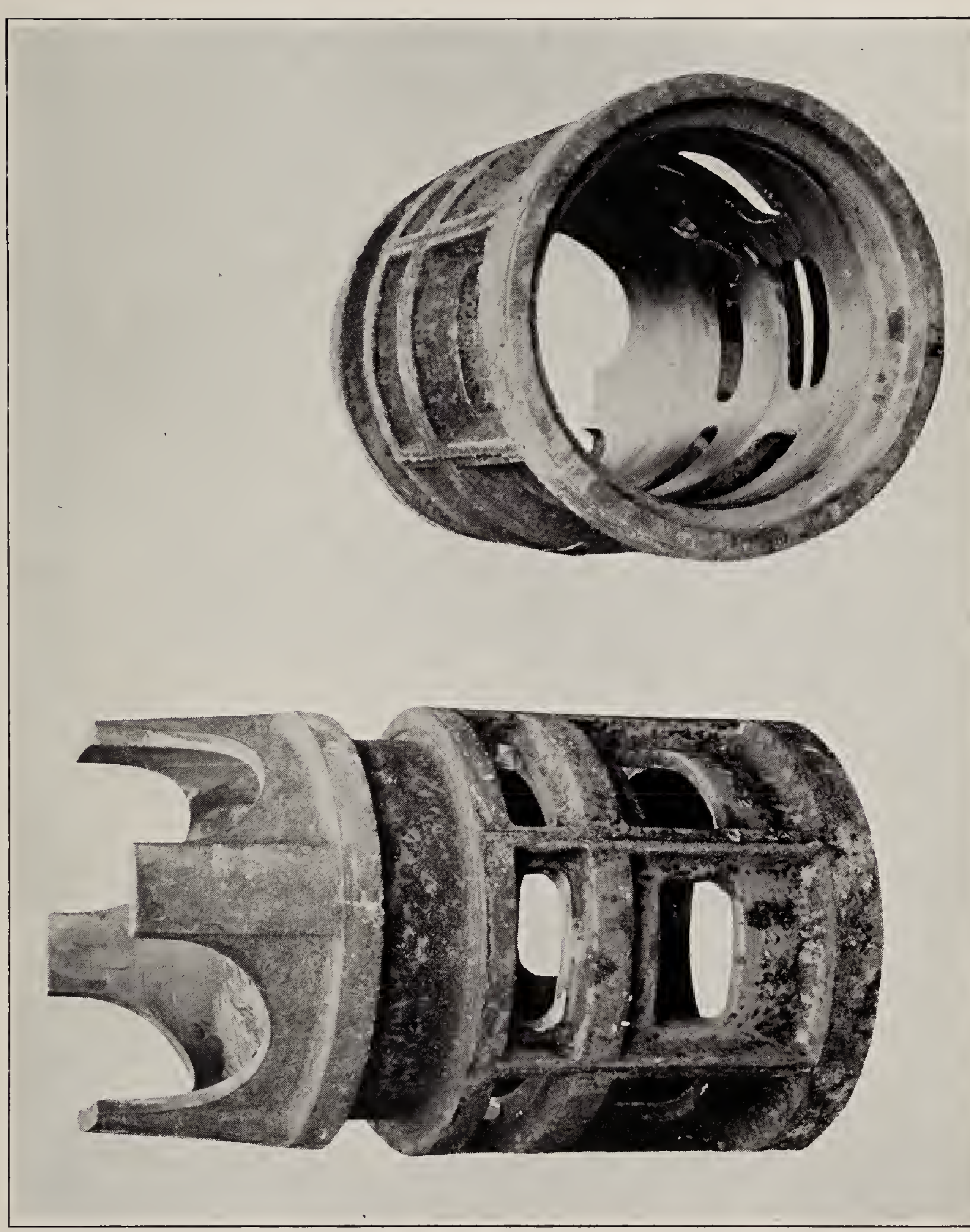


Fig. 23.

VALVE CAGE FOR ADAPTING THE 12-INCH VALVE.

This form of valve cage is used where the old cylinders have steam chests for valves larger than 12-inch.

M. P. 394 A—Sixth Sheet

9-25-13
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-6-2
CLASS K2sa
NUMBER 877

FUEL: Penn Gas Coal
Bulletin No.23

SUBJECT: Piston Valve Diameter - 16 in. Valves.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3001	120-25-F	2.00	27.98	Full	20.1	Rectang	205.6	3.1	0.03	14207	
3028	200-25-F	2.00	46.52	"	29.6	-ular	204.9	5.9	0.09	14724	
3011	200-35-F	2.00	46.52	"	33.8	Area	204.8	7.6	0.07	14735	
3017	200-50-F	1.00	46.52	"	50.9	33.25 "	206.0	14.5	0.12	14735	
3012	240-25-F	1.50	55.82	"	27.9	"	206.0	7.1	0.07	14735	
3013	240-35-F	1.50	55.82	"	36.3	"	205.4	9.4	0.10	14735	
3020	240-50-F	1.00	55.82	"	50.4	"	196.4	15.0	0.11	14724	
3014	280-25-F	1.50	65.13	"	29.8	"	204.9	8.0	0.09	14735	
3015	280-35-F	1.00	65.13	"	35.9	"	205.6	10.9	0.10	14735	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3001	2181	40.67	18588	24326	5.64	11.13	705.1	76.02		198.4	169.3
3028	3690	68.69	28913	38728	8.98	10.50	1122.6	69.20		193.4	226.7
3011	4300	80.04	32877	44589	10.34	10.37	1292.4	68.29		189.5	249.5
3017	7183	133.71	45621	62702	14.54	8.73	1817.4	57.49		179.7	290.8
3012	4031	75.04	31111	41728	9.68	10.35	1209.5	68.16		191.7	227.4
3013	5105	95.03	36605	49749	11.54	9.75	1442.0	64.21		187.8	255.7
3020	7882	146.72	47155	64711	15.01	8.21	1875.7	54.11		167.3	286.5
3014	4049	75.37	32660	44139	10.24	10.90	1279.4	71.78		189.8	240.7
3015	5728	106.63	39705	54100	12.55	9.44	1568.1	62.16		185.1	269.2

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3001	18075	972.2	2.25	18.6	1.6	10236	763.8	2.9	23.7	78.6	6.3	
3028	28466	1687.4	2.19	16.9	5.4	11897	1475.9	2.5	19.3	87.5	6.9	
3011	32491	1908.7	2.25	17.0	6.8	13844	1717.5	2.5	18.9	90.0	6.9	
3017	45076	2339.7	3.07	19.3	13.9	16843	2089.5	3.4	21.6	89.3	5.0	
3012	30776	1910.0	2.11	16.1	6.0	9399	1399.2	2.9	22.0	73.3	6.0	
3013	35968	2160.5	2.36	16.7	8.3	10522	1566.4	3.3	23.0	72.5	5.3	
3020	46778	2411.0	3.27	19.4	13.3	13978	2080.9	3.8	22.5	86.3	4.6	
3014	32351	2104.0	1.92	15.4	7.7	10258	781.7	2.3	18.2	84.7	7.6	
3015	39128	2399.9	2.39	16.3	10.5	11192	1943.9	2.3	20.1	81.0	5.9	

M. P. 394 A—Sixth Sheet

9-25-13
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-6-2
CLASS K2sa
NUMBER 877

FUEL: Penn Gas Coal
Bulletin No.23

SUBJECT: Piston Valve Diameter - 11 in. Valve.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3031	120-25-F	2.00	27.91	Full	25.6	Rectang-	203.9	3.7	0.04	14350	
3032	200-25-F	2.00	46.52	"	24.3	-lar	205.0	4.8	0.04	14350	
3033	200-35-F	1.50	46.52	"	31.3	Area	204.5	6.3	0.07	14350	
3038	200-50-F	1.00	46.52	"	48.8	32.25 "	203.6	12.5	0.15	14399	
3034	240-25-F	1.50	55.82	"	26.1	"	204.1	5.5	0.07	14350	
3035	240-35-F	1.50	55.82	"	31.0	"	204.7	7.7	0.10	14350	
3039	240-50-F	1.00	55.82	"	47.5	"	204.4	14.4	0.17	14399	
3040	240-55-F	1.00	55.82	"	52.0	"	201.1	16.7	0.14	14399	
3036	280-25-F	1.50	65.13	"	25.2	"	205.1	6.6	0.07	14399	
3037	280-35-F	1.00	65.13	"	31.5	"	202.9	8.7	0.06	14399	

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3031	2929	54.5	20755	27444	6.4	9.4	795.5	63.4		199.1	179.5
3032	2929	54.5	24870	33340	7.7	11.4	966.4	77.0		198.2	214.0
3033	3905	72.7	28753	38692	9.0	9.9	1121.5	67.0		194.6	222.1
3038	6673	124.2	40779	55564	12.9	8.3	1610.6	56.1		183.9	263.6
3034	3423	63.7	27091	36384	8.4	10.6	1054.6	71.9		196.2	217.3
3035	4361	81.2	32281	43654	10.1	10.0	1265.3	67.7		194.1	238.4
3039	6889	128.2	44876	61495	14.3	8.9	1782.5	60.2		182.1	275.1
3040	8004	149.0	47800	65106	15.1	8.1	1887.1	54.8		175.0	266.6
3036	3520	65.5	29144	39213	9.1	11.1	1136.6	75.1		194.4	227.5
3037	4835	90.0	33900	46151	10.7	9.5	1337.7	64.3		189.3	255.5

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3031	20042	1099.9	2.7	18.2	2.0	12569	935.6	3.1	21.4	85.1	5.7	
3032	24124	1514.1	1.9	15.9	3.9	10320	1280.3	2.3	18.8	84.6	7.7	
3033	28464	1756.7	2.2	16.2	5.0	12333	1530.0	2.6	18.6	87.1	7.0	
3038	40434	2186.8	3.1	18.5	10.8	16390	2033.3	3.3	19.9	93.0	5.4	
3034	26749	1738.0	2.0	15.4	5.3	9125	1358.5	2.5	19.7	78.2	7.0	
3035	31897	1982.9	2.2	16.1	7.3	11220	1670.3	2.6	19.1	84.2	6.8	
3039	44140	2402.4	2.9	18.4	14.7	13037	1940.8	3.6	22.7	80.8	5.0	
3040	47420	2399.2	3.3	19.8	15.3	13537	2015.3	4.0	23.5	84.0	4.5	
3036	28649	1919.1	1.8	14.9	6.2	8438	1465.5	2.4	19.6	76.4	7.4	
3037	32976	2162.0	2.2	15.3	8.0	9678	1680.9	2.9	19.6	77.8	6.1	

M. P. 394 A—Sixth Sheet

9-25-13
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-6-2
CLASS K2sa
NUMBER 877

FUEL: Penn Gas Coal

Bulletin No.23

SUBJECT: Piston Valve Diameter - 12 in. Valve.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3394	120-20-F	2.00	28.30	Full	39.1	Four	205.0	5.8	0.09	14553	
3395	120-20-F	1.50	28.30	"	39.4	Internal	205.0	5.8	0.09	14553	
3303	200-35-F	2.00	47.16	"	39.1	Project	205.1	9.0	0.12	14590	
3304	200-35-F	1.50	47.16	"	38.7	Area	205.2	9.1	0.12	14590	
3309	240-25-F	1.50	56.59	"	26.0	33.32 "	204.9	6.8	0.09	14590	
3310	240-25-F	1.00	56.59	"	25.8	"	204.9	6.8	0.09	14590	
3311	240-35-F	1.50	56.59	"	40.1	"	204.8	10.5	0.12	14590	
3312	240-35-F	1.00	56.59	"	39.4	"	205.0	10.6	0.14	14590	
3314	240-50-F	1.00	56.59	"	51.2	"	186.9	14.0	0.11	14723	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3394	3463	64.47	28396	36288	8.4	10.5	1051.8	69.9		193.4	143.2
3395	3460	64.41	28310	36302	8.4	10.5	1052.2	70.0		193.8	150.4
3303	4923	91.64	35883	46874	10.9	9.5	1358.7	63.3		189.4	199.1
3304	4876	90.77	35887	47004	10.9	9.6	1362.4	64.1		189.6	205.6
3309	3348	62.32	30911	39873	9.3	11.9	1155.8	79.2		193.0	163.7
3310	3402	63.33	30517	39448	9.2	11.6	1143.4	77.2		192.9	168.5
3311	5244	97.62	39457	51697	12.0	9.9	1498.4	65.6		186.1	204.1
3312	5172	96.28	39243	51526	12.0	10.0	1493.5	66.3		186.7	209.4
3314	8846	164.67	45624	59945	13.9	6.8	1737.5	44.7		159.3	220.2

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3394	18481	1402.1	2.5	20.0	4.5	16312	1230.8	2.8	22.8	87.8	6.2	
3395	18378	1406.8	2.5	19.9	4.2	16461	1242.1	2.8	22.5	88.3	6.3	
3303	35623	1932.5	2.6	18.4	6.7	12918	1624.5	3.0	21.9	84.1	5.8	
3304	35593	1941.0	2.5	18.3	6.5	12794	1608.8	3.0	22.1	82.9	5.8	
3309	30708	1765.5	1.9	17.4	6.4	8382	1264.9	2.7	24.3	71.7	6.6	
3310	30283	1758.1	1.9	17.2	6.2	8311	1254.2	2.7	24.1	71.3	6.4	
3311	39188	2281.4	2.4	18.0	9.5	10698	1614.4	3.3	24.3	74.0	5.4	
3312	38958	2195.3	2.4	17.8	9.0	10628	1603.9	3.2	24.3	73.0	5.4	
3314	45427	2244.5	3.9	20.2	12.1	11530	1740.0	5.1	26.1	77.5	3.4	

M. P. 394 A—Sixth Sheet

9-25-13
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd
NUMBER 318

FUEL: Penn Gas Coal

Bulletin No.23

SUBJECT: Piston Valve Diameter - 14 in. Valves.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3112	120-30-F	2.00	28.01	Full	25.2	Rectangu-	205.2	4.4	0.12	14442	
3115	200-35-F	2.00	46.68	"	32.7	-lar	205.0	9.3	0.23	"	
3135	200-35-F	1.00	46.68	"	31.1	Area	206.0	8.0	0.12	14581	
3124	200-45-F	1.50	46.68	"	41.5	25.44 "	203.0	12.3	0.34	14266	
3139	240-45-F	1.00	56.02	"	41.9	"	196.4	12.8	0.21	14581	
3109	240-45-F	1.00	56.02	"	42.1	"	195.9	13.7	0.41	14442	

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe, Degrees F.
	338	339	340	344	345	347	349	350		220	230
3112	2240	41.64	18085	23532	9.9	10.5	682.1	70.6		199.2	138.4
3115	4042	75.15	26924	35641	15.0	8.8	1033.1	59.3		193.2	179.3
3135	3663	68.29	25650	34513	14.5	9.4	1000.4	62.7		194.7	227.4
3124	5491	102.01	32885	44275	18.6	8.1	1283.6	54.9		186.0	232.3
3139	5977	111.44	33970	46078	19.4	7.7	1335.6	51.3		178.0	253.8
3109	5703	106.03	34737	46073	19.4	8.1	1335.4	54.3		175.6	193.4

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3112	17828	945.1	2.4	18.9	3.3	9516	710.6	3.2	29.8	75.2	5.59	
3115	26644	1548.9	2.6	17.2	7.2	9953	1238.8	3.3	21.5	80.0	5.41	
3135	25343	1574.8	2.3	16.0	4.6	10763	1339.6	2.7	18.9	85.0	6.39	
3124	32353	1820.6	3.0	17.8	11.5	12357	1538.0	3.6	21.0	84.5	5.00	
3139	33628	1959.0	3.1	17.2	11.8	10536	1573.6	3.8	21.4	78.5	4.59	
3109	34360	1861.8	3.1	18.5	12.7	10274	1534.4	3.7	22.4	82.4	4.74	

M. P. 394 A—Sixth Sheet

9-25-13
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd
NUMBER 318

FUEL: Penn Gas Coal
Bulletin No.23

SUBJECT: Piston Valve Diameter - 10 in. Valve.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3144	120-30-F	2.00	27.9	Full	30.4	Rectangu	205.2	4.8	0.13	14541	
3145	200-35-F	1.50	46.5	"	37.9	-lar	205.1	10.4	0.27	"	
3148	200-45-F	1.00	46.5	"	44.4	Area	201.6	12.6	0.25	"	
3149	200-50-F	1.00	46.5	"	46.8	25.44 "	192.4	12.1	0.29	"	
3146	240-40-F	1.25	55.8	"	41.8	"	192.2	12.7	0.20	"	
3147	240-40-F	1.00	55.8	"	42.5	"	200.0	12.2	0.30	"	

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3144	2404	44.0	19321	25512	10.7	10.6	739.5	70.8		198.7	175.4
3145	5331	97.5	29854	40199	16.9	7.5	1165.2	50.3		190.4	228.3
3148	6402	117.0	33211	44704	18.8	7.0	1295.8	46.6		183.7	230.2
3149	5538	101.2	34177	46147	19.4	8.3	1337.6	55.6		173.6	237.4
3146	5307	97.0	31910	43368	18.2	8.2	1257.1	54.5		174.2	257.8
3147	5472	100.0	33516	45613	19.2	8.3	1322.1	55.7		182.3	260.0

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3144	18867	1053.4	2.3	17.9	2.4	11354	845.1	2.8	22.3	80.2	6.2	
3145	29538	1736.1	3.1	17.0	9.2	11573	1435.7	3.7	20.6	82.7	4.7	
3148	32873	1839.2	3.5	17.9	12.0	12455	1545.2	4.1	21.3	84.0	4.2	
3149	33877	1804.2	3.1	18.8	13.0	12322	1528.7	3.6	22.2	84.7	4.8	
3146	31552	1831.1	2.9	17.2	10.5	9838	1464.6	3.6	21.5	80.0	4.8	
3147	33171	1922.9	2.9	17.3	11.8	10366	1543.2	3.6	21.5	80.3	4.9	

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9-28-13
8 x 10½

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd
NUMBER 318

FUEL: Penn Gas Coal

Bulletin No.23

SUBJECT: Piston Valve Diameter - 7 in. Valve.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	Pressure in Boiler, Lbs. per Sq. inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3150	120-30-F	1.00	27.9	Full	30.9	Rectang	205.0	4.2	0.14	14541	
3151	200-35-F	1.50	46.5	"	33.9	-ular	204.7	7.1	0.22	14541	
3152	200-45-F	1.00	46.5	"	43.8	Area	203.6	10.8	0.32	14541	
3155	200-45-F	1.00	46.5	"	44.2	25.44 "	203.6	11.8	0.29	14360	
3154	200-50-F	1.00	46.5	"	45.6	"	197.4	11.8	0.31	14360	
3156	200-50-F	1.00	46.5	"	46.8	"	198.7	12.8	0.31	14360	
3153	240-40-F	1.00	55.8	"	39.5	"	199.0	11.1	0.29	14360	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3150	1966	35.9	18014	23699	10.0	12.1	686.9	80.4		199.1	166.2
3151	3173	58.0	24756	33109	13.9	10.4	959.7	69.6		194.2	209.1
3152	5219	95.4	31079	41729	17.5	8.0	1209.5	53.4		186.3	222.5
3155	5894	107.8	31035	41905	17.6	7.1	1214.6	48.1		188.9	234.0
3154	6876	125.7	31680	42803	18.0	6.2	1240.7	42.0		179.3	236.9
3156	6488	118.6	31359	42607	17.9	6.6	1235.0	44.4		182.6	249.8
3153	6145	112.3	29882	40394	17.0	6.6	1170.8	44.4		184.7	235.2

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3150	17717	986.0	2.0	18.0	3.4	11258	838.0	2.4	21.1	85.0	7.5	
3151	24477	1452.5	2.2	16.9	7.3	10160	1260.4	2.5	19.4	86.8	7.0	
3152	30745	1703.2	3.1	18.1	11.3	12525	1553.9	3.4	19.8	91.2	5.2	
3155	30538	1710.2	3.5	17.9	11.5	11741	1456.6	4.1	21.0	85.2	4.4	
3154	31389	1687.3	4.1	18.6	10.7	12287	1524.3	4.5	20.6	90.3	3.9	
3156	31007	1730.8	3.8	17.9	11.7	12238	1518.2	4.3	20.4	87.7	4.2	
3153	29439	1702.9	3.6	17.3	10.3	9536	1419.6	4.3	20.7	83.4	4.1	

M. P. 394 A—Sixth Sheet
3 x 10½

11-9-10

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb
NUMBER 387

FUEL: Jamison Coal

Bulletin No.23

SUBJECT: Piston Valve Diameter - 14 in. Piston Valve.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3205	60-20-F	0.75	10.8	Full	21.9	Rectangu	205.8	1.3	0.13	14661	
3209	60-30-F	1.50	10.8	"	33.0	-lar	206.0	2.0	0.10	"	
3202	80-30-F	1.50	14.4	"	34.6	Area	205.3	2.4	0.09	"	
3204	80-40-F	1.75	14.4	"	42.8	30.88 "	205.5	3.2	0.15	"	
3236	100-50-F	1.00	18.0	"	50.1	"	205.4	5.8	0.15	13330	
3221	120-30-F	2.00	21.6	"	33.9	"	205.9	3.7	0.22	13843	
3220	140-40-F	1.00	25.2	"	41.5	"	204.9	5.9	0.31	"	
3222	160-35-F	1.00	28.8	"	37.9	"	203.3	5.9	0.28	"	
3235	160-40-F	1.00	28.8	"	32.3		198.7	6.4	0.27	13330	
3224	170-35-F	1.00	30.5	"	38.6	"	204.1	5.8	0.31	13330	

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3205	1467	26.51	12744	16333	4.62	11.13	473.4	73.7		201.2	101.2
3209	2033	36.74	16494	21250	6.01	10.45	615.9	69.2		201.5	130.1
3202	2489	44.98	19769	25659	7.26	10.31	743.7	68.2		202.0	132.8
3204	3189	57.63	23567	30804	8.71	9.66	892.9	63.9		199.4	152.1
3236	4897	88.49	30959	41030	11.60	8.38	1189.3	61.0		196.6	200.6
3221	3429	61.96	24757	32282	9.13	9.41	935.7	66.0		199.8	155.6
3220	5300	95.77	31681	41510	11.74	7.83	1203.2	54.9		196.0	168.9
3222	5101	92.18	30244	39499	11.17	7.74	1144.9	54.3		194.7	167.5
3235	5585	100.92	32666	43086	12.18	7.71	1248.9	56.1		189.1	193.9
3224	4870	86.00	30826	40581	11.47	8.33	1176.3	60.6		195.4	126.8

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3205	12474	599.2	2.5	20.8	0.8	16221	468.3	3.1	26.6	78.2	5.6	
3209	16137	842.5	2.4	19.2	0.8	23480	677.9	3.0	23.8	80.5	5.8	
3202	19489	1050.1	2.4	18.6	2.1	22695	873.7	2.9	22.3	83.2	6.1	
3204	23259	1252.4	2.6	18.6	2.3	28053	1079.9	2.9	21.5	86.2	5.9	
3236	30650	1657.0	2.3	18.5	6.1	31518	1516.6	3.2	20.2	91.5	5.9	
3221	24397	1394.2	2.5	17.5	4.9	19779	1535.4	3.0	21.4	81.9	6.1	
3220	31399	1786.3	3.0	17.6	8.0	22791	1412.4	3.5	20.5	86.0	5.3	
3222	29934	1738.1	3.0	17.2	7.4	18515	1142.1	3.6	21.0	82.0	5.1	
3235	32320	1829.9	3.0	17.7	8.2	19924	1534.0	3.6	21.0	83.9	5.3	
3224	30519	1813.4	2.7	16.9	7.3	17835	1459.0	3.3	20.9	80.5	5.7	

M. P. 394 A—Sixth Sheet

9-25-13
8 x 10½"

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb
NUMBER 387

FUEL: Jamison Coal

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No.23

SUBJECT: Piston Valve Diameter - 12 in. valve.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3263	60-25-F	2.00	10.7	Full	24.8	Rectangu	205.6	1.6	0.07	13614	
3248	60-30-F	2.00	10.7	"	30.0	-lar	206.0	2.6	0.08	14140	
3262	80-30-F	2.00	14.3	"	30.1	Area	206.0	2.2	0.04	13614	
3249	80-40-F	2.00	14.3	"	39.7	30.88	205.7	3.3	0.12	14140	
3250	100-50-F	1.00	17.9	"	50.0	"	204.4	6.2	0.09	14140	
3261	120-30-F	2.00	21.5	"	33.5	"	205.8	3.7	0.08	13614	
3252	140-40-F	1.00	25.1	"	41.0	"	203.0	5.8	0.19	14033	
3260	140-43-F	1.00	25.1	"	45.0	"	204.4	6.5	0.10	13614	
3254	160-35-F	1.00	28.6	"	35.9	"	202.6	4.9	0.11	14033	
3256	160-40-F	1.00	28.6	"	39.9	"	198.7	6.3	0.10	14033	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3263	1679	30.3	14374	18504	5.2	11.0	536.3	78.6		201.2	132.2
3248	2183	39.5	16607	21406	6.1	9.8	620.5	67.3		201.8	129.1
3262	2250	40.7	18493	23979	6.8	10.7	695.0	76.0		200.7	150.1
3249	2910	52.6	22983	30141	8.5	10.4	873.7	71.1		199.9	169.7
3250	5217	94.3	32779	43347	12.3	8.3	1256.4	57.0		194.0	200.8
3261	3284	59.3	23742	31196	8.8	9.5	904.2	67.7		199.2	178.7
3252	4905	88.6	30801	40582	11.5	8.3	1176.3	57.2		194.3	183.5
3260	5832	105.4	33248	43960	12.4	7.5	1274.2	53.7		194.4	196.9
3254	4335	78.3	28642	37779	10.7	8.7	1095.0	60.2		195.1	192.3
3256	4658	84.2	30539	40363	11.4	8.7	1169.9	60.0		189.3	197.7

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3263	14286	625.9	2.7	22.8	1.3	18600	532.7	3.2	26.8	85.1	5.9	
3248	16319	748.4	2.9	21.8	1.2	22481	643.8	3.4	25.4	86.0	5.3	
3262	18398	892.7	2.5	20.6	2.0	19660	750.7	3.0	24.5	84.1	6.2	
3249	22721	1161.6	2.5	19.6	2.7	26522	1012.7	2.9	22.4	87.2	6.3	
3250	32463	1664.5	3.1	19.5	6.7	30872	1473.5	3.5	22.0	88.5	5.1	
3261	23664	1198.2	2.7	19.8	4.0	18127	1038.2	3.2	22.8	86.7	5.9	
3252	30521	1630.0	3.0	18.7	7.1	20961	1400.7	3.5	21.8	85.9	5.2	
3260	33135	1772.1	3.3	18.7	8.1	23148	1546.8	3.8	21.4	87.3	5.0	
3254	28314	1570.4	2.8	18.0	6.6	17524	1338.3	3.2	21.2	85.2	5.6	
3256	30244	1668.2	2.8	18.1	7.5	18975	1449.1	3.2	20.9	86.9	5.7	

M. P. 394 A—Sixth Sheet

9-25-13
8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb
NUMBER 387

FUEL. Jamison Coal

Bulletin No.23

SUBJECT: Piston Valve Diameter - 12 in. Piston Valve.

ALTOONA, PA., 9-1-1913

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders	EXHAUST NOZZLE	Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
3259	160-40-F	1.00	28.6	Full	40.3	Rectang	205.6	5.9	0.14	13614	
3257	170-35-F	1.00	30.4	"	35.3	-lar	206.0	5.5	0.12	14033	
3258	170-40-F	1.00	30.4	"	39.0	Area	205.3	6.0	0.14	14033	
						30.88 "					

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel		Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
3259	5374	97.1	31585	41922	11.9	7.8	1215.1	55.6		196.4	205.4
3257	4589	82.9	29870	39251	11.1	8.6	1137.7	59.1		197.1	181.7
3258	4905	88.6	33297	44158	12.5	9.0	1279.9	62.2		195.9	204.5

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds	Least Back Pressure	Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
3259	31432	1734.6	3.1	18.1	7.3	19881	1518.3	3.5	20.7	87.5	5.3	
3257	29496	1597.4	2.1	18.5	7.0	16553	1343.1	3.4	22.0	84.1	5.3	
3258	33020	1778.9	2.8	18.6	8.4	18727	1519.5	3.2	21.7	85.4	5.6	

PART II.

VALVE STEM STRESS.

TESTS FOR THE PURPOSE OF DETERMINING THE MAGNITUDE OF THE STRESSES TO WHICH VALVE STEMS ARE SUBJECTED UNDER THE CONDITIONS OF LOCOMOTIVE OPERATION.

INTRODUCTION.

1. It is evident that a change in the diameter of a piston valve alters its weight and its frictional resistance to movement. The resistances are no doubt increased when valve leakage occurs and the valve becomes unbalanced. At high speeds inertia effects also appear and add to the stress in the valve rod.

2. The relative magnitude of the stresses which are thus imposed upon valve gears by piston valves of different diameters on locomotives either in freight or passenger service has been, to a considerable extent, a matter of either conjecture or theory.

3. Therefore, in making this somewhat elaborate study of the proper size of piston valves to use with our locomotives, an investigation of the subject of valve stem stresses was made.

4. The tests were made while the valve diameter tests were in progress, and the same locomotives were used as in the valve diameter tests. With the use of the locomotive test plant these investigations were made with a degree of accuracy otherwise impossible. The method adopted for recording the valve stem stress was to interpose a steel ball and an impression plate in the valve stem, so that the stresses in the stem would be transmitted through the ball and impression plate, an impression being made by the ball in the steel plate as a measure of the intensity of the valve stem stress.

It is not asserted that the impressions are a perfectly reliable indication of the exact stress. The stress is difficult to measure by any means, and it is thought that this method gives approximate if not accurate results, or, at any rate, a comparison of the effects due to the different valves.

Description of Valve Stem Stress Indicator.

5. The device used for determining the stresses in the valve stem is illustrated in Figs. 24 to 26. It consists of a valve stem yoke, 1, Fig. 24. a spring yoke, 2, two helical springs, 3, whose lengths are $5\frac{5}{8}$ inches when uncompressed. These springs are seated at one end in the spring yoke and are held in place by eye bolts, 4, attached to the valve stem yoke. The springs are compressed and released by the nuts, 5, or by the movement of the valve and its stem when the locomotive is in operation.

6. In order to apply this device it was necessary to design a new valve stem gland, 6, in order to give sufficient clearance between the gland and the valve stem yoke, 1. A special valve stem crosshead, 7, was substituted for the one on the locomotive. The end of the valve stem was threaded at 8 to receive the spring yoke, 1, and a slot was cut close to the crosshead shoulder to receive the impression plate, 9.

7. The load on the valve stem was transferred to the impression plate through a hardened steel ball, 10, which was 0.3937 inch in diameter. The ball was held in place by a hardened steel block having a seat ground in its center, Fig. 26.

8. The impression plates, Figs. 24 and 26, one of which was used for each individual test, were made from one boiler plate for each locomotive. The boiler plate was thoroughly annealed before machining to insure the small plates being all of the same quality of material. The plates were polished on one side, which face was used to receive the impression from the small steel ball.

9. A sample impression plate was placed in a reliable testing machine and various loads were placed upon it, increasing gradually to a maximum considered sufficient for the purpose of this investigation. With each load a separate impression was made on the plate, these impressions increasing in depth and surface diameter with each increase in the pressure applied.

10. From the information thus obtained curves were plotted with the diameters of the impressions as abscissæ and the loads on the steel ball in pounds as ordinates. As different sets of plates were used for each locomotive, Figs. 27, 28 and 29 represent the stress curves for the K2sa, E3sd and H8sb locomotives respectively. These curves were used in determining the stresses from the impressions made upon other plates during the tests.

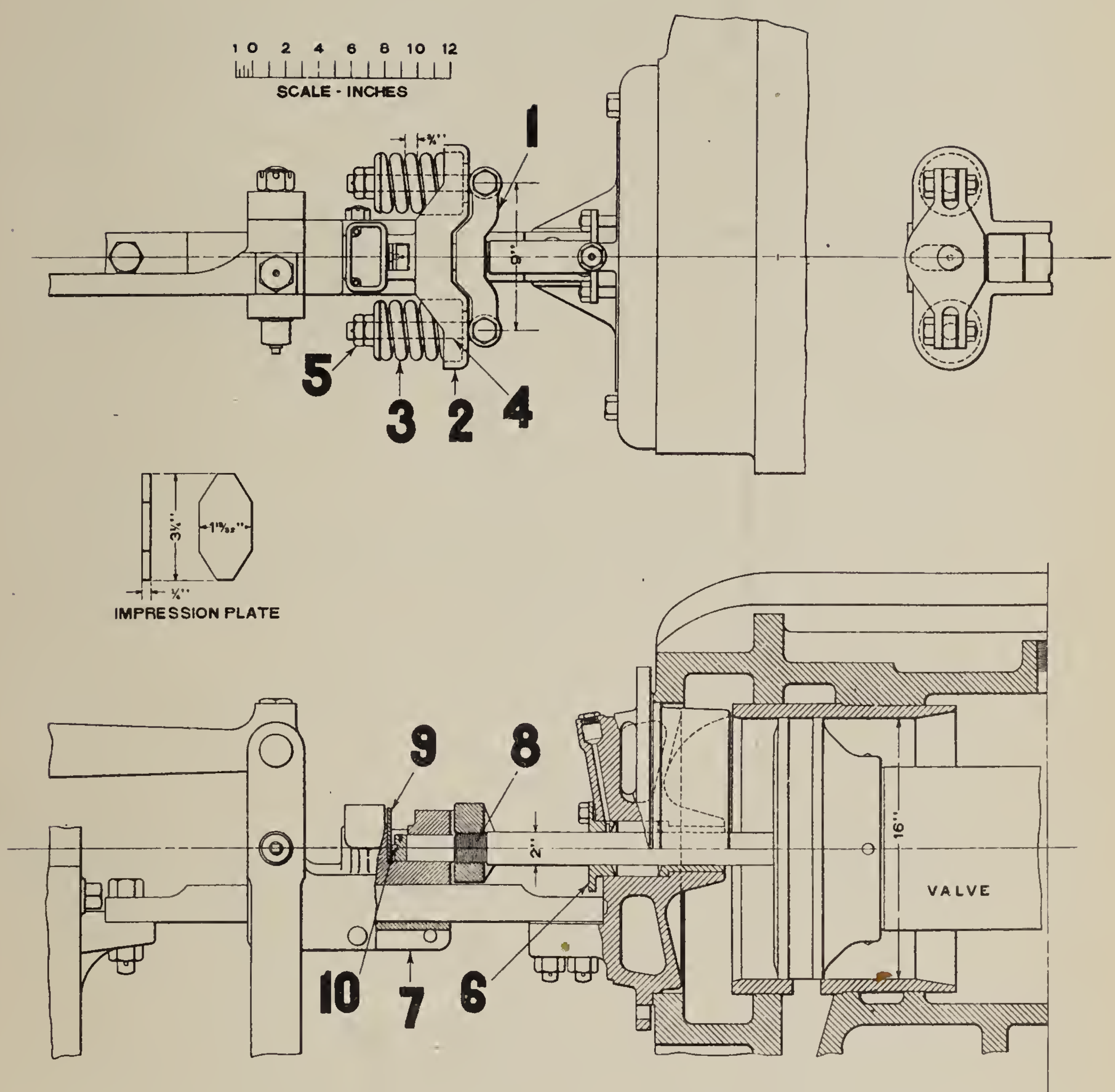

Fig. 24.

VALVE STEM STRESS INDICATOR.

This drawing shows the valve stem stress indicator as applied to the K2sa locomotive with a 16-inch valve.

Method of Conducting Tests.

11. The method of conducting the tests to determine the valve stem stress was as follows: An impression plate was inserted in the slot and the springs were compressed by drawing up the nuts with a wrench to some specified distance, indicating a definite load in pounds. Both springs were previously calibrated, and when drawn up solid to 4¼ inches indicated a load of 4770 pounds. The springs were then released and the impression plate was removed. The load imposed upon the plate left its impression mark, which was measured and recorded.

12. The plate was returned to the slot and the nuts again adjusted until the compression of the springs was exactly the same as before. Thus was assured the same assumed load on ball and plate as in the first instance. The locomotive was then quickly brought up to speed and run for two minutes at a speed and cut-off at which the valve stem stress was to be determined. The springs were then loosened, the impression plate removed and the enlarged impression measured. The plate, shown in Fig. 26, has two impressions, one (A) registering a definite load obtained from the spring, the other (B) this spring load plus an additional load imposed by the operation of the valve under steam pressure.

13. Tests were made in this manner on the locomotive for speeds ranging from 40 to 360 r.p.m. and cut-offs from 20 to 88 per cent.

Locomotives Equipped with Different Size Valves for Determining the Valve Stem Stresses.

14. Descriptions of locomotives Nos. 877, 318 and 387 are given in Bulletins Nos. 18, 11 and 10 respectively. They are simple superheated steam locomotives carrying a boiler pressure of 205 pounds gauge. The total valve travel on the K2sa No. 877 and the E3sd No. 318 is 7 inches, while that on the H8sb No. 387 is 6 inches.

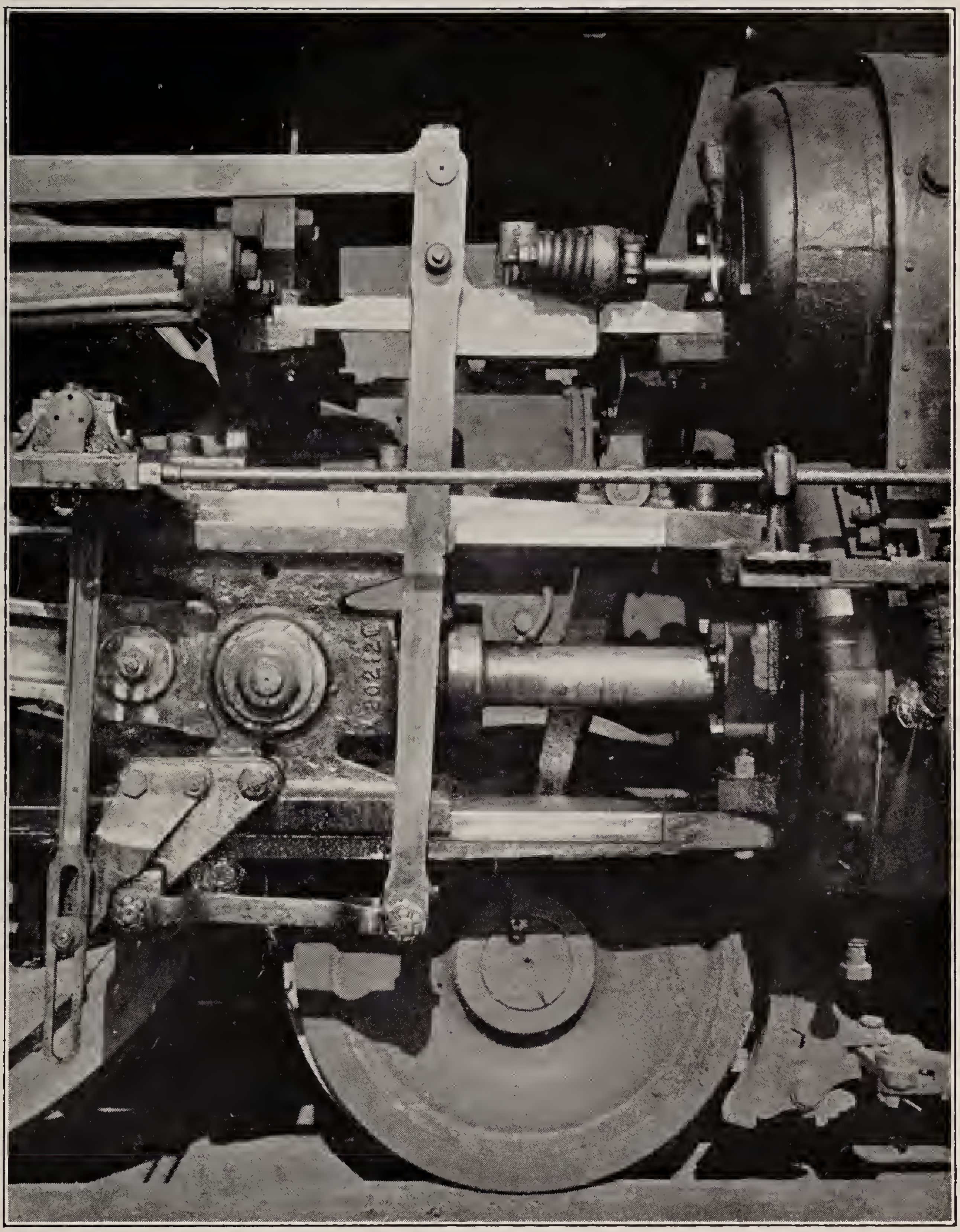

Fig. 25.
VALVE STEM STRESS INDICATOR.
The indicator on a K2sa locomotive.

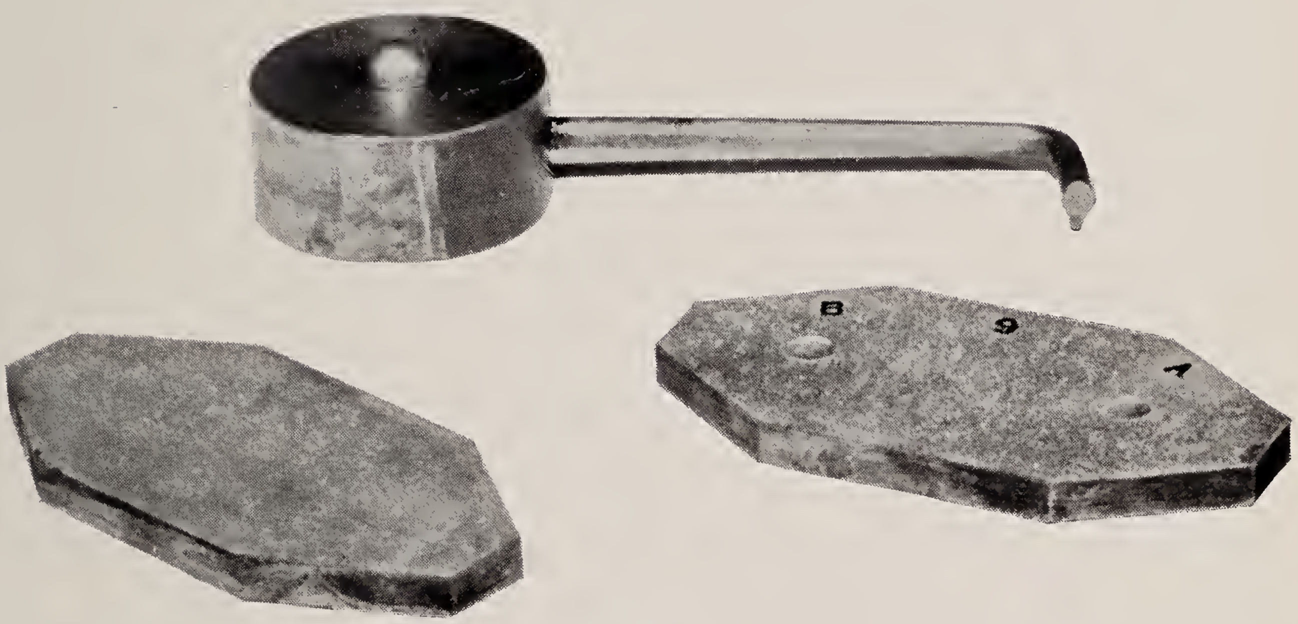

Fig. 26.

IMPRESSION PLATES AND STEEL BALL.

A blank plate and a plate with impressions are shown. The impression at A was made by the spring alone; that at B is the combined spring and valve stress impression. The 10 mm. steel ball is shown in its holder. The holder has a stem for use in inserting and removing it from the valve stem crosshead.

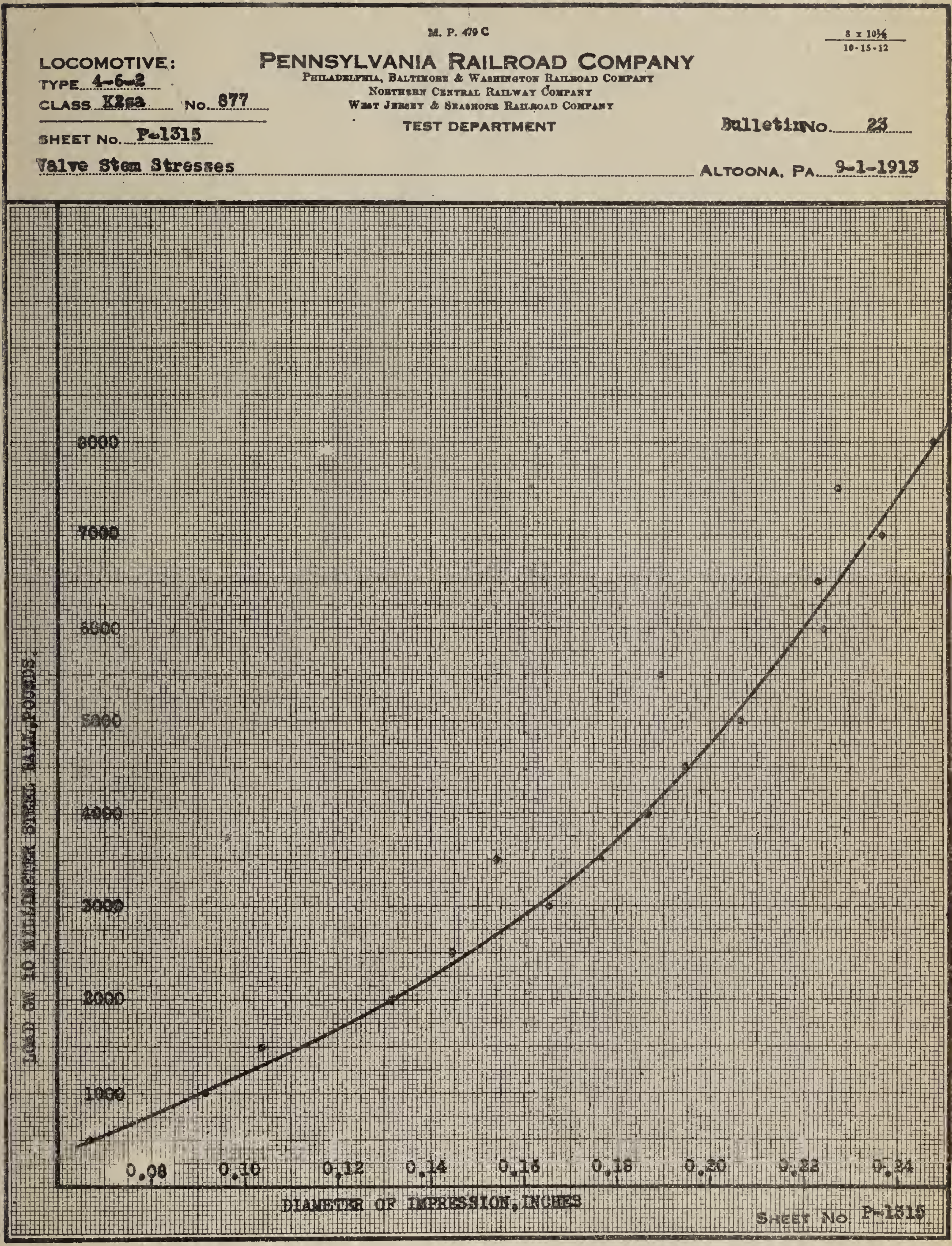

Fig. 27.

CURVE FOR BALL IMPRESSION.

This curve shows the diameter of impression of a 10-millimeter steel ball with testing machine loads from 500 to 8000 pounds. Curve used for K2sa locomotive.

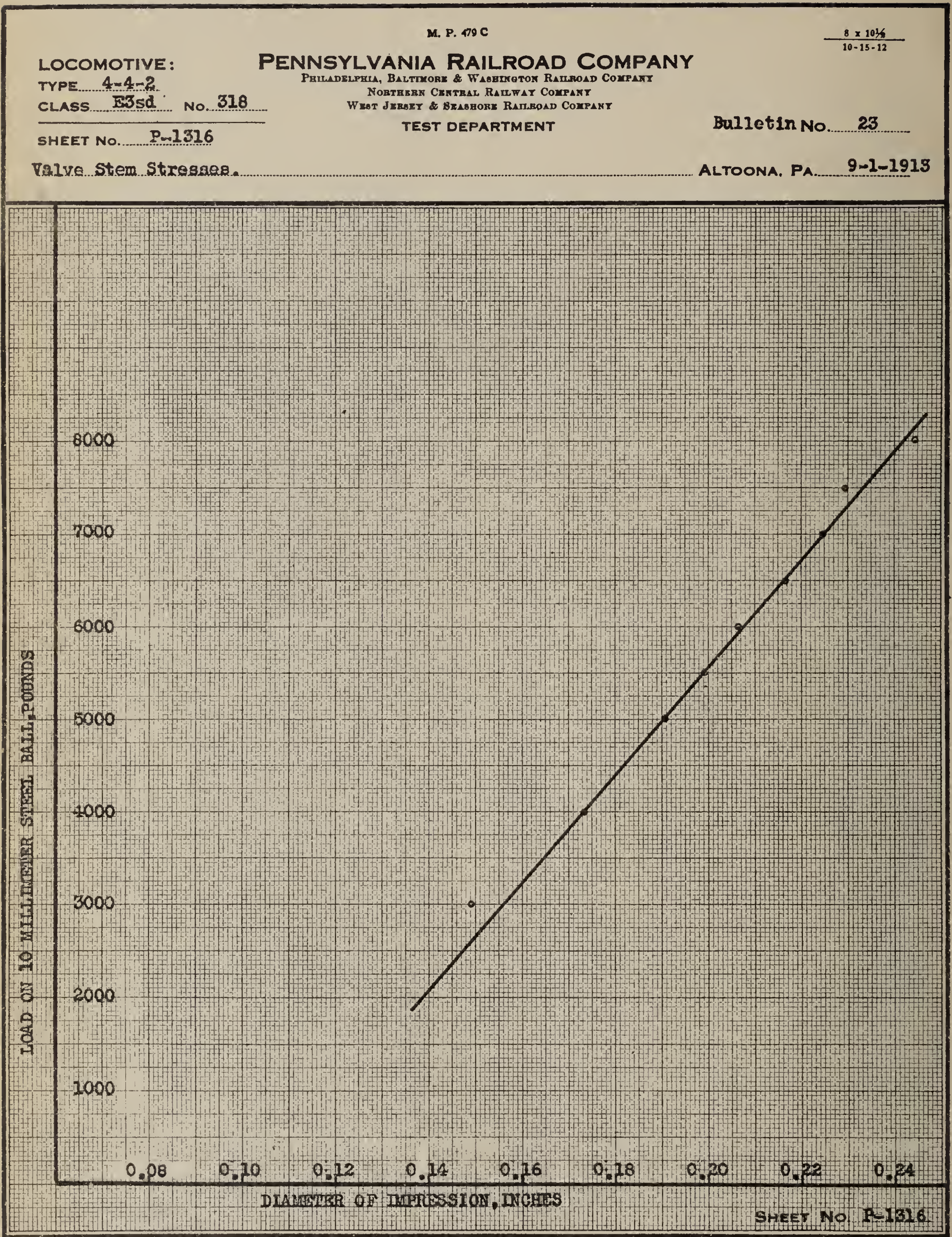

Fig. 28.

CURVE FOR BALL IMPRESSION.

The diameter of impression of a 10-millimeter steel ball with testing machine loads from 2000 to 8000 pounds. Curve used for E3sd locomotive.

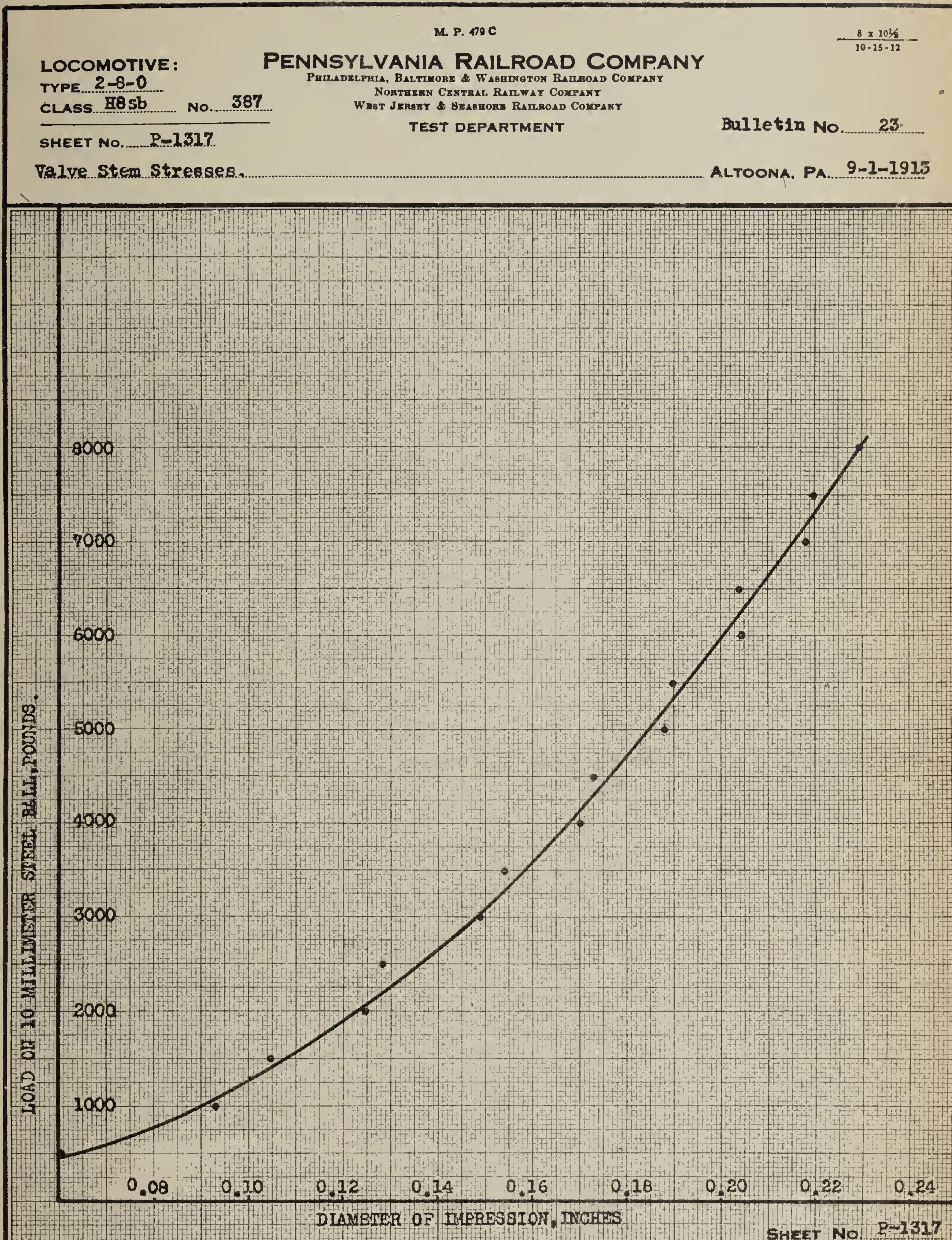

Fig. 29.

CURVE FOR BALL IMPRESSION.

The diameter of impression of a 10-millimeter steel ball with testing machine loads from 500 to 8000 pounds.

Curve used for H8sb locomotive.

Valves Used for Valve Stem Stresses.

15. The valve, Fig. 3, used on the K2sa Pacific type locomotive No. 877 was of the L ring type, having a diameter of 16 inches. Later a 12-inch valve, Fig. 22 A, of the L ring type was applied. Both valves are designed for inside admission and are described in the fore part of this bulletin. The weight of the 16-inch valve is 263 pounds while that of the 12-inch valve is 120 pounds.

16. The standard piston valve, Fig. 8, used on the E3sd Atlantic type locomotive was a 14-inch L ring valve with inside admission. Later a 7-inch valve, Fig. 10, of the L ring type was applied. The weight of the 14-inch valve is 218 pounds and that of the 7-inch valve 76 pounds.

17. The H8sb consolidation type locomotive was equipped with 12-inch valves, Fig. 22-A, of the L ring type. The weight of this valve is 136 pounds. It is longer than the valve for the K2sa, which weighs 120 pounds. The weights given in each instance are exclusive of the weight of the valve stem.

The Tests.

18. There were twenty tests made with the Pacific type locomotive No. 877, using the 16-inch valve. These tests were run at speeds ranging between 9 and 84 miles per hour and cut-offs between 25 and 85 per cent. The throttle was fully open.

19. The table following indicates the number of tests made at each speed and cut-off:

Locomotive No. 877—16-Inch Piston Valve.

R. P. M.	M. P. H.	Nominal Cut-off in Per Cent. of Stroke													
		25	30	35	40	45	50	55	60	65	70	75	80	83	85
40	9.3	......	......	......	......	......	......	......	......	......	......	......	......	1	1
80	18.6	......	......	......	......	......	......	......	......	......	......	1	1		
120	28.0	......	......	......	......	......	......	......	......	1	1				
160	37.3	......	......	......	......	......	......	1	1						
200	46.5	......	......	......	......	......	1	1							
240	55.8	......	......	......	......	1	1								
280	65.1	......	......	......	1	1									
320	74.4	......	1	1	1										
360	83.7	1	1	1											

20. Later, nineteen tests were made on this locomotive with a 12-inch L ring piston type valve. The same range of piston speed and cut-off was adhered to as in the previous tests, also a wide-open throttle.

21. A table showing the number of tests run at each speed and cut-off follows:

LOCOMOTIVE NO. 877—12-INCH PISTON VALVE.

L Ring Type Valve.

R.P.M.	M.P.H.	Nominal Cut-off in Per Cent. of Stroke													
		25	30	35	40	45	50	55	60	65	70	75	80	83	85
40	9.3	......	......	......	......	......	......	......	......	......	......	......	......	1	1
80	18.6	......	......	......	......	......	......	......	......	......	......	1	1		
120	28.0	......	......	......	......	......	......	......	......	1	1				
160	37.3	......	......	......	......	......	......	1	1						
200	46.5	......	......	......	......	......	1	1							
240	55.8	......	......	......	......	1	1								
280	65.1	......	......	......	1	1									
320	74.4	......	......	......	1										
360	83.7	2	1	1											

22. On the Atlantic type locomotive No. 318, class E3sd, sixteen tests were run with the 14-inch valves. The tests were run with a fully open throttle at speeds ranging between 23 and 65 miles per hour with cut-offs between 20 and 45 per cent.

23. There follows a table showing the number of tests made at each speed and cut-off:

LOCOMOTIVE NO. 318—14-INCH PISTON VALVE.

American Type Valve.

R.P.M.	M.P.H.	Nominal Cut-off in Per Cent. of Stroke					
		20	25	30	35	40	45
100	23.3	......	......	2			
120	28.0	......	......	1	......	1	
160	37.3	......	1	......	......	......	1
200	46.7	......	3	......	......	......	1
240	56.0	3	......	2			
280	65.4	......	1				

There were also made on this Atlantic type locomotive eleven tests, using a 7-inch L ring type valve. These tests were run over the same range of speed and cut-off as the previous tests with the 14-inch valve.

24. The following table gives the number of tests under each speed and cut-off:

LOCOMOTIVE NO. 318—7-INCH PISTON VALVES.
L Ring Type Valve.

R. P. M.	M. P. H.	NOMINAL CUT-OFF IN PER CENT. OF STROKE				
		20	25	30	40	45
100	23.3			1		
120	28.0			1	1	
160	37.3		1			1
200	46.7		1			1
240	56.0	1		1		
280	65.4		2			

25. Thirty tests were made on locomotive No. 387, consolidation type, class H8sb, using the 12-inch L ring type valve. These tests were run at speeds ranging between 7 and 30.5 miles per hour and cut-offs between 20 and 88 per cent. All tests were made with a wide-open throttle.

26. The outline following shows the number of tests under each speed and cut-off:

LOCOMOTIVE NO. 387—12-INCH PISTON VALVE.
L Ring Type Valve.

R. P. M.	M. P. H.	NOMINAL CUT-OFF IN PER CENT. OF STROKE									
		20	30	40	43	45	50	58	63	68	88
40	7.2	1		1					1		1
60	10.8	1		1					1		1
80	14.4	1		1				1		1	
100	18.1	1	1	1			1				
120	21.6	1	1	1		1					
140	25.2	1	1	1	1						
160	28.8	1	1	1							
170	30.5	1	1	1							

Piston Valve Stresses.

27. There are presented in Tables X to XIV, inclusive, the stresses in pounds under which the valve rods were working at different speeds and cut-offs on the K2sa locomotive No. 877, the E3sd locomotive No. 318 and the H8sb locomotive No. 387.

28. Each table includes the impression plate number, the test designation, giving the speed in r.p.m. and the nominal cut-off in per cent., the diameter of the impression in the impression plate with the spring load applied, and, after the test was made, the spring load applied in pounds; the spring plus the valve load, in pounds, and the stress in the valve stem in pounds.

29. Referring to Table X, it is observed that on the K2sa Pacific type locomotive No. 877, using 16-inch piston valves, the stress in the valve stem increased from 1350 pounds at a speed of 40 r.p.m. (9 m.p.h.) and 83 per cent. cut-off to 5825 pounds at a speed of 360 r.p.m. (84 m.p.h.) and 35 per cent. cut-off. This indicates that the stress in the valve stem increases with the speed of the locomotive.

30. With the application of the 12-inch L ring type of valve the stress, Table XI, increased from 1240 pounds to 4600 pounds through the same range of speed and cut-off.

31. Thus, on this locomotive the application of the smaller 12-inch piston valve decreased the stress in the valve rod 110 pounds at 9 miles per hour and 1225 pounds at 84 miles per hour.

32. An abnormal pressure is shown at a speed of 84 m.p.h. and 25 per cent. cut-off when the stress recorded was 7465 pounds, due to the breaking of the valve in this instance. This was the highest valve stress obtained during these experiments.

33. The Atlantic type locomotive No. 318, using 14-inch piston valves, Table XII, developed a stress in the valve stem ranging between a minimum of 2010 pounds at 100 r.p.m., 23 m.p.h. and 30 per cent. cut-off, and a maximum of 4170 pounds at 240 r.p.m., 56 m.p.h. and 30 per cent. cut-off, while with the 7-inch valves, Table XIII, the stress increased from 2190 pounds to 3030 pounds through the same range of speeds and cut-offs.

M. P. 479—A

351J 1-24 13
8 x 10½

LOCOMOTIVE:
TYPE 4-6-2
CLASS K2sa No. 877

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 23

SHEET NO. P-1318

Valve Stem Stresses - 16 in. Piston Valve. ALTOONA, PA. 9-1-1913

Impression Plate Number	Test Designation	Diameter of Impression Inches		Spring Load Pounds	Spring and Valve Load Pounds	Stress in Valve Stem Pounds
		With Spring Load	After Test Was Made			
15-A	40-83-F	0.1968	0.2204	4550	5900	1350
16-A	40-85-F	0.2002	0.2287	4730	6450	1720
8-B	80-75-F	0.1936	0.2196	4390	5875	1485
11-A	80-80-F	0.2020	0.2364	4835	7015	2180
7-B	120-65-F	0.1974	0.2305	4590	6575	1985
14-B	120-70-F	0.2003	0.2355	4740	6975	2235
12-A	160-55-F	0.1976	0.2315	4590	6650	2060
7-A	160-60-F	0.1833	0.2281	3875	6475	2600
5-A	200-50-F	0.1444	0.2012	2375	4790	2415
6-A	200-55-F	0.1664	0.2277	3160	6375	3215
1-A	240-45-F	0.1776	0.2364	3625	7000	3375
10-A	240-50-F	0.1977	0.2531	4600	8400	3800
2-A	280-40-F	0.1641	0.2200	3075	5875	2800
11-B	280-45-F	0.2029	0.2597	4875	9000	4125
3-A	320-30-F	0.1521	0.2153	2640	5600	2960
9-B	320-35-F	0.1945	0.2521	4425	8320	3895
13-B	320-40-F	0.2082	0.2674	5175	9720	4545
4-A	360-25-F	0.1642	0.2316	3075	6675	3600
4-B	360-30-F	0.1516	0.2372	2610	7075	4465
16-B	360-35-F	0.1992	0.2784	4675	10500	5825

SHEET NO. P-1318

Table X.

VALVE STEM STRESSES—16-INCH VALVE.

This table shows the diameter of impression and the stress in the valve stem for speeds from 40 revolutions to 360 revolutions per minute, corresponding to 9 and 84 miles per hour. K2sa locomotive.

M. P. 479—A

351J 5-11-12
8 x 10½

LOCOMOTIVE:
TYPE 4-6-2
CLASS K2sa No. 877

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 23

SHEET NO. P-1319

Valve Stem Stresses - 12 in. Piston Valve. ALTOONA, PA. 9-1-1913

Impression Plate Number	Test Designation	Diameter of Impression Inches		Spring Load Pounds	Spring and Valve Load Pounds	Stress in Valve Stem Pounds
		With Spring Load	After Test Was Made			
35-A	40-83-F	0.1985	0.2186	5710	6950	1240
35-B	40-85-F	0.1996	0.2186	5785	6950	1165
37-B	80-75-F	0.1918	0.2296	5350	7660	2310
36-B	80-80-F	0.1924	0.2238	5360	7275	1915
29-A	120-65-F	0.1911	0.2248	5290	7315	2025
29-B	120-70-F	0.1906	0.2300	5255	7675	2420
28-A	160-55-F	0.1719	0.2136	4225	6640	2415
28-B	160-60-F	0.1723	0.2161	4240	6800	2560
26-A	200-50-F	0.1806	0.2163	4685	6800	2115
36-A	200-55-F	0.1880	0.2288	5125	7600	2475
31-A	240-45-F	0.1919	0.2335	5350	7900	2550
20-B	240-50-F	0.1535	0.2109	3250	6460	3210
21-A	280-40-F	0.1459	0.2110	3875	6475	2600
21-B	280-45-F	0.1513	0.2111	3140	6475	3335
23-A	320-40-F	0.1555	0.2250	3350	7350	4000
32-A	360-25-F	0.1773	0.2475	4500	8800	4300
33-B	360-25-F	0.1842	0.3257	4885	12350	7465
25-A	360-30-F	0.1733	0.2284	4275	7575	3300
27-A	360-35-F	0.1827	0.2565	4800	9400	4600

SHEET NO. P-1319

Table XI.

VALVE STEM STRESSES—12-INCH VALVE.

The diameter of impression and the stress in the valve stem for speeds from 40 revolutions to 360 revolutions per minute, corresponding to 9 and 84 miles per hour. K2sa locomotive. The stress of 7465 pounds was caused by the valve rings catching in one of the ports and breaking the head of the valve.

M. P. 479—A

351J 5-11-12
8 x 10½

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY
TEST DEPARTMENT

Bulletin No. 23

SHEET NO. P-1320

Valve Stem Stresses - 14 in. Piston Valve. ALTOONA, PA. 9-1-1913

Impression Plate Number	Test Designation	Diameter of Impression Inches: With Spring Load	Diameter of Impression Inches: After Test Was Made	Spring Load Pounds	Spring and Valve Load Pounds	Stress in Valve Stem Pounds
50	100-30-F	0.1748	0.2344	4075	7475	3400
59	100-30-F	0.1802	0.2187	4400	6410	2010
52	120-30-F	0.1797	0.2154	4350	6400	2050
51	120-40-F	0.1740	0.2175	4050	6530	2480
54	160-25-F	0.1741	0.2141	4030	6470	2440
53	160-45-F	0.1766	0.2210	4200	6890	2690
61	200-25-F	0.1965	0.2255	5350	8520	3170
60	200-25-F	0.1841	0.2282	4620	7140	2520
56	200-25-F	0.1762	0.2402	4150	7720	3570
55	200-45-F	0.1745	0.2208	4075	6975	2900
65	240-20-F	0.1987	0.2497	5475	8415	2930
58	240-20-F	0.1780	0.2341	4275	7910	3640
63	240-20-F	0.1860	0.2379	4750	8020	3270
62	240-30-F	0.1908	0.2431	5000	8690	3690
57	240-30-F	0.1734	0.2372	4000	8170	4170
64	280-25-F	0.2032	0.2454	5725	8755	3030

SHEET NO. P-1320

Table XII.

VALVE STEM STRESSES—14-INCH VALVE.

The diameter of impression and the stress in the valve stem for speeds from 100 revolutions to 280 revolutions per minute, corresponding to 23 and 65 miles per hour. E3sd locomotive.

M. P. 479—A

351J 1-24 13
8 x 10½

LOCOMOTIVE:
TYPE 4-4-2
CLASS E3sd No. 318

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

SHEET NO. P-1321

Bulletin No. 23

Valve Stem Stresses - 7 in. Piston Valves. ALTOONA, PA. 9-1-1913

Impression Plate Number	Test Designation	Diameter of Impression Inches		Spring Load Pounds	Spring and Valve Load Pounds	Stress in Valve Stem Pounds
		With Spring Load	After Test Was Made			
17	100-30-F	0.1774	0.2105	4250	6440	2190
15	120-30-F	0.1737	0.1969	4025	5425	1400
16	120-40-F	0.1716	0.2062	3900	5790	1890
13	160-25-F	0.1728	0.2058	3950	5790	1840
14	160-45-F	0.1757	0.2017	4125	5695	1570
11	200-25-F	0.1702	0.2080	3830	6130	2300
12	200-45-F	0.1691	0.2204	3750	6620	2870
9	240-20-F	0.1764	0.2195	4180	6528	2340
10	240-30-F	0.1683	0.2152	3700	6730	3030
7	280-25-F	0.1715	0.2103	3900	6630	2730
6	280-25-F	0.1853	0.2276	4700	7120	2420

SHEET NO. P-1321

Table XIII.

VALVE STEM STRESSES—7-INCH VALVE.

The diameter of impression and the stress in the valve stem for speeds from 100 revolutions to 280 revolutions per minute, corresponding to 23 and 65 miles per hour. E3sd locomotive.

M. P. 479—A

851J 5-11-12
8 x 10½

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

SHEET No. P-1322

Valve Stem Stresses - 12 in. Piston Valves.

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 23

ALTOONA, PA. 9-1-1913

Impression Plate Number	Test Designation	Diameter of Impression Inches		Spring Load Pounds	Spring and Valve Load Pounds	Stress in Valve Stem Pounds
		With Spring Load	After Test Was Made			
23-BX	40-20-F	0.1484	0.1875	3050	5160	2110
24-B	40-40-F	0.1420	0.1838	2750	4925	2175
25-B	40-63-F	0.1496	0.1871	3100	5150	2050
26-B	40-88-F	0.1439	0.1939	2840	5560	2720
23-A	60-20-F	0.1503	0.1878	3110	5175	2065
24-A	60-40-F	0.1417	0.1846	2725	4980	2255
27-B	60-63-F	0.1499	0.1980	3110	5815	2705
28-B	60-88-F	0.1570	0.2278	3450	7875	4425
21-A	80-20-F	0.1441	0.1888	2840	5230	2390
28-A	80-40-F	0.1503	0.1969	3115	5750	2635
21-B	80-58-F	0.1481	0.1946	3050	5575	2525
22-B	80-68-F	0.1559	0.2014	3400	6130	2730
14-A	100-20-F	0.1486	0.1948	3060	5620	2560
11	100-30-F	0.1280	0.1786	2200	4625	2425
12	100-40-F	0.1469	0.1956	2975	5675	2700
13-A	100-50-F	0.1476	0.2030	3000	6125	3125
13-B	120-20-F	0.1543	0.2051	3325	6310	2985
14-B	120-30-F	0.1533	0.2031	3275	6275	3000
15-A	120-40-F	0.1456	0.1985	2900	5900	3000
16-A	120-45-F	0.1471	0.2044	3000	6275	3275
15-BX	140-20-F	0.1604	0.2110	3600	6700	3100
16-B	140-30-F	0.1531	0.2099	3250	6625	3375
17-A	140-40-F	0.1625	0.2175	3725	7150	3425
27-A	140-43-F	0.1500	0.2079	3110	6500	3390
17-B	160-20-F	0.1640	0.2197	3800	7275	3475
18-BXX	160-30-F	0.1471	0.2060	2975	6360	3385
19-A	160-40-F	0.1662	0.2252	3910	7675	3765
20-A	170-20-F	0.1545	0.2125	3350	6800	3450
19-B	170-30-F	0.1682	0.2258	4000	7700	3700
20-BX	170-40-F	0.1440	0.2129	2840	6815	3975

SHEET No. P-1322

Table XIV.

VALVE STEM STRESSES—12-INCH VALVE.

The diameter of impression and the stress in the valve stem for speeds from 40 revolutions to 170 revolutions per minute, corresponding to 7 and 30 miles per hour. H8sb locomotive.

34. It is noticeable that with this locomotive the valve stem stress at 280 r.p.m., 65 m.p.h. and 25 per cent. cut-off is somewhat below that at 240 r.p.m., which is probably due to the condition of the valve at the period of the two-minute test, for a study of the valve stresses indicates that the load varies at intervals, due possibly to the condition of the lubricant and steam.

35. It is likewise noticeable in this instance, as might previously have been anticipated, that the smaller valve is instrumental in decreasing the stress in the valve stem to an appreciable extent at high speeds.

36. The valve stem stresses, Table XIV, for the H8sb consolidation type locomotive No. 387, equipped with the 12-inch piston valves, ranged between 2110 pounds at 40 r.p.m., 7 m.p.h. and 20 per cent. cut-off and 3975 pounds at 170 r.p.m., 30.5 m.p.h. and 40 per cent. cut-off.

Valve Stem Stress and Speed of Locomotive.

37. As observed in the foregoing tables, the tendency is for the valve stem stress to increase with the speed of the locomotive. This is more clearly shown in a graphical way by the following figures:

38. Fig. 30 presents the stresses for the K2sa locomotive No. 877 plotted with the revolutions per minute as abscissæ for the 16-inch and 12-inch valves. In each instance the stress increases with the speed. Comparing the valve stem stresses for the two different valves, it is observed that the stress for the 12-inch valve is slightly greater than for the larger 16-inch valve up to 160 r.p.m., 37 m.p.h., when they are nearly equal; thereafter the valve stem stress for the larger 16-inch valve increases rapidly above that for the 12-inch as the speed of the locomotive is increased.

39. Referring to Fig. 31 there is plotted the valve stem stress for the 7-inch and 14-inch valves on the E3sd locomotive No. 318, with the speed in revolutions per minute. Here, again, is observed the increase in the valve stem stress as the speed of the locomotive is increased. The greater valve stem stress for the 14-inch valve is at once apparent.

40. Fig. 32 shows the valve stem stresses for the H8sb locomotive No. 387, using the 12-inch valves. The valve stem stress likewise increases with the speed, but more gradually than in the case of the higher speed K2sa and E3sd locomotives.

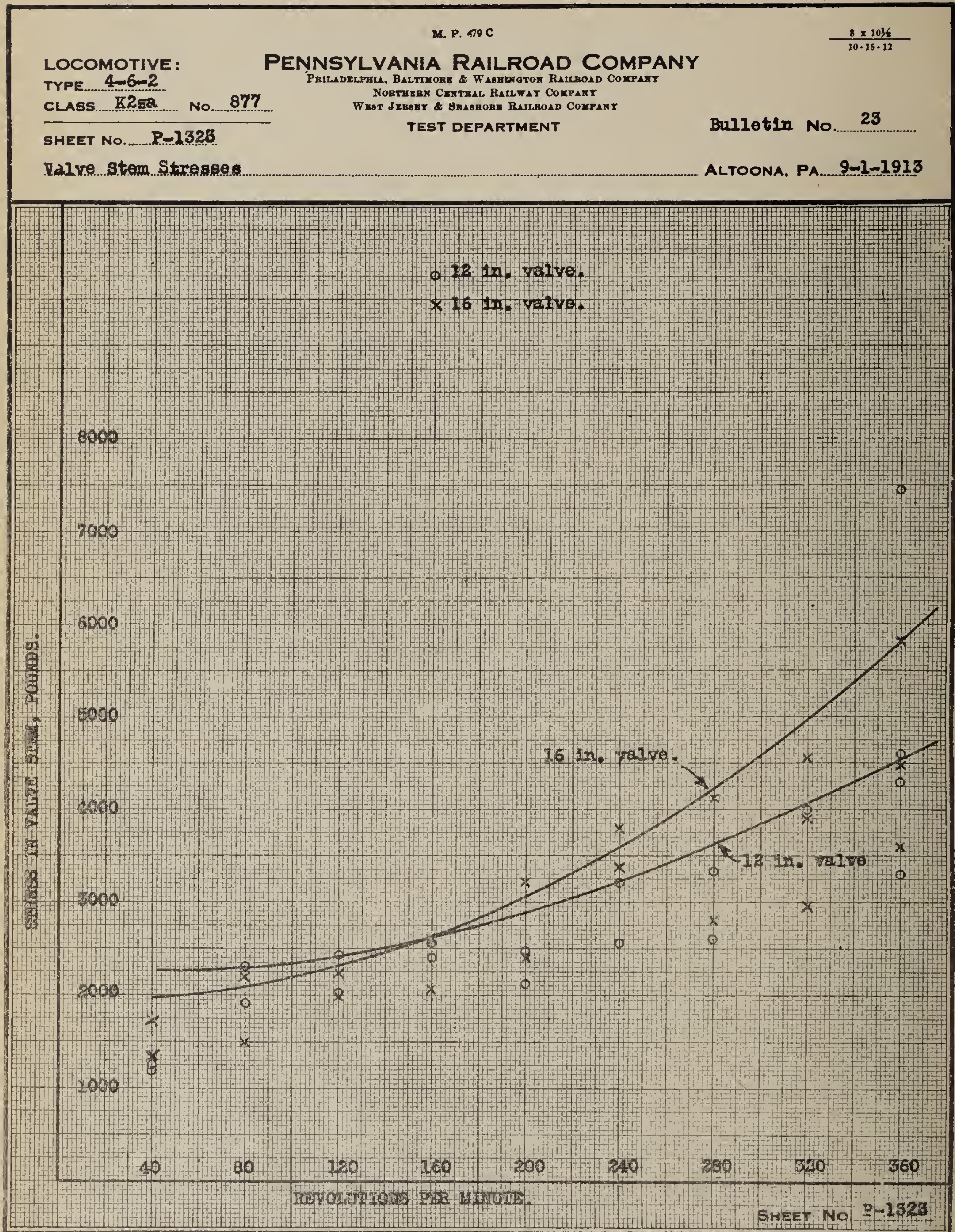

Fig. 30.

STRESS IN VALVE STEM.

This diagram shows stresses for 12- and 16-inch valves on a K2sa locomotive. It indicates that the 16-inch valve, which weighs 244 pounds, has stresses up to 6000 pounds at 85 miles per hour; the 12-inch, weighing 120 pounds, has stresses up to 4600 pounds at 85 miles per hour. The single stress of 7465 pounds was caused by a broken valve.

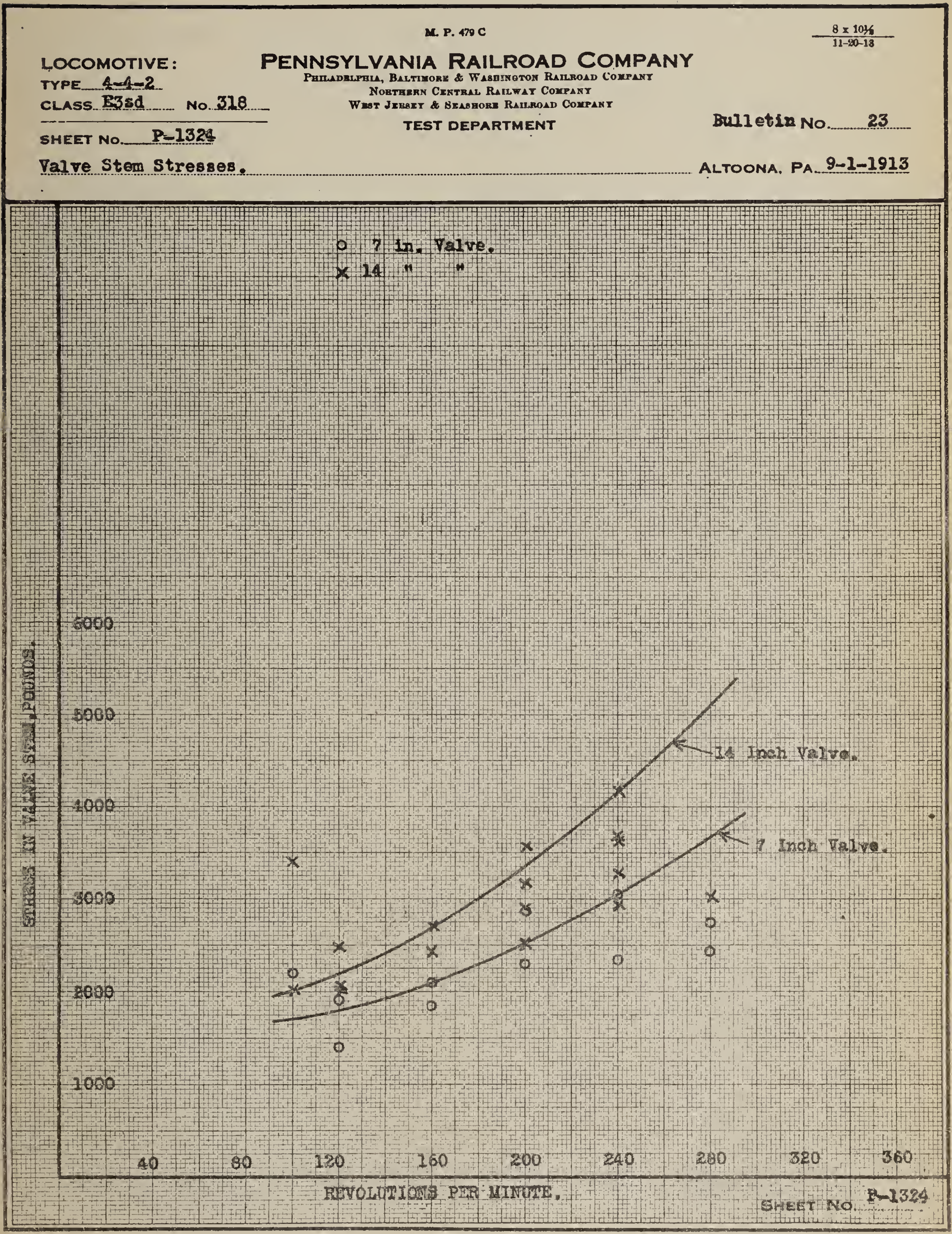

Fig. 31.

STRESS IN VALVE STEM.

Stresses for 14 and 7-inch valves on E3sd locomotive. The 14-inch valve, which weighs 218 pounds, has stresses up to 5000 pounds at 65 miles per hour; the 7-inch valve, weighing 76 pounds, has stresses up to 3500 pounds at 65 miles per hour.

M. P. 479 C

8 x 10½
10-15-12

LOCOMOTIVE:
TYPE 2-8-0
CLASS H8sb No. 387

SHEET No. P-1325

Valve Stem Stresses

PENNSYLVANIA RAILROAD COMPANY
PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
NORTHERN CENTRAL RAILWAY COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

Bulletin No. 23

ALTOONA, PA. 9-1-1913

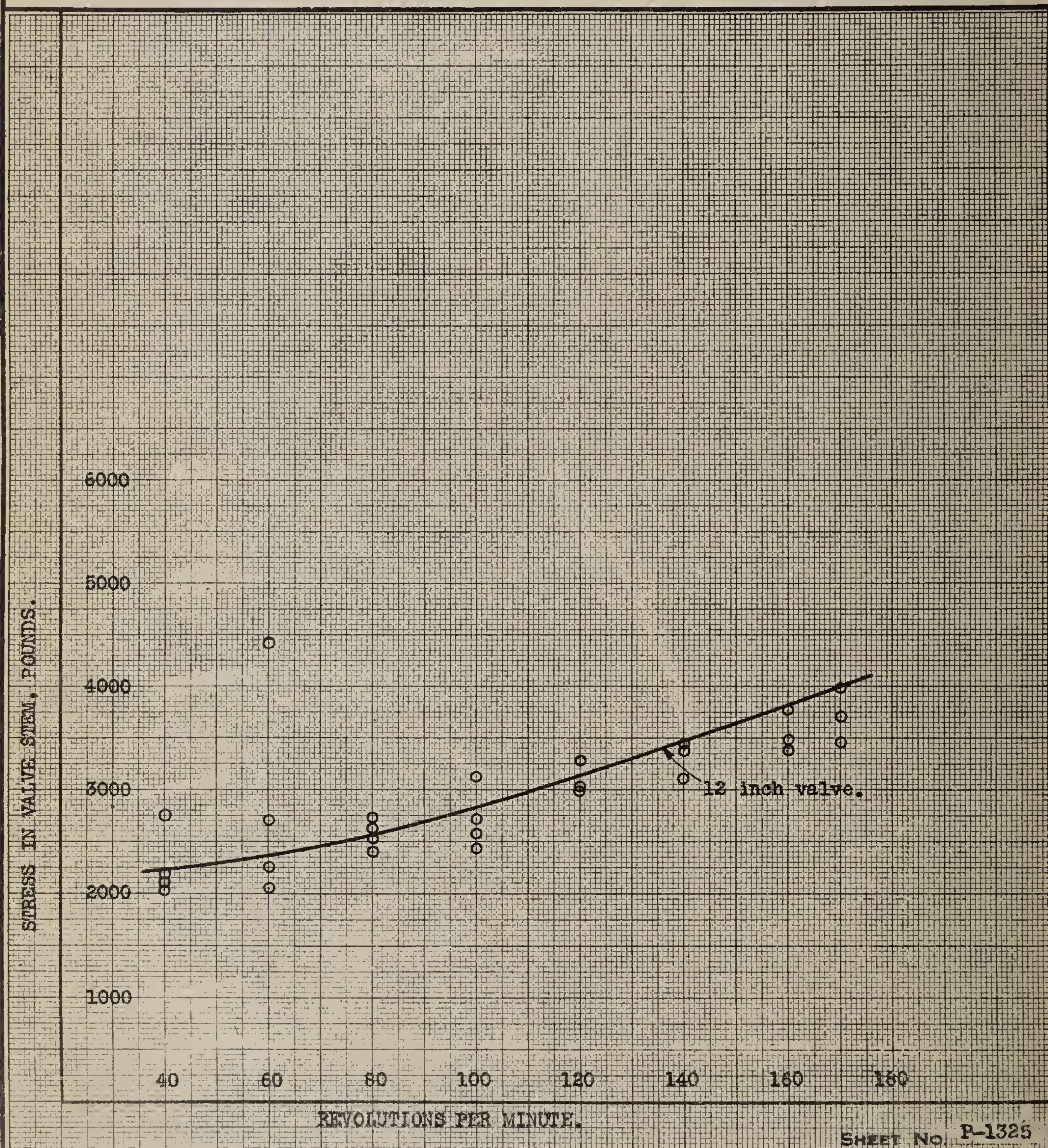

Fig. 32.
STRESS IN VALVE STEM.
Stresses for a 12-inch valve on a H8sb locomotive. The 12-inch valve, which weighs 136 pounds, has stresses up to 4000 pounds at 30 miles per hour.

CONCLUSIONS.

Valve Stem Stress.

1. The experiments have proven that the stress on a locomotive valve stem increases—

(*a*) With the increase in the speed.

(*b*) With the increase in cut-off.

(*c*) With the increase in the diameter, and consequently the weight of the valve.

2. The valve stem stresses on a high-speed Pacific type locomotive with a 16-inch valve, weighing 244 pounds, range between 1350 and 5825 pounds, while with the 12-inch valve, weighing 120 pounds, the stress increases from 1165 to 4600 pounds.

3. The valve stem stresses on an E3sd Atlantic type locomotive with a 14-inch valve, weighing 218 pounds, range between 2010 and 4170 pounds, and with a 7-inch valve, weighing 76 pounds, the stress is from 1400 up to 2730 pounds.

4. The valve stem stresses on an H8sb consolidation type locomotive with a 12-inch valve, weighing 136 pounds, range between 2050 and 3975 pounds.

5. The diameter of the valve stem used on these locomotives is sufficient to withstand these loads with a safe margin of strength.

6. These tests further show the advantage to be gained by using a smaller and lighter piston valve wherever possible, for such a valve not only reduces the stresses in the valve gear, but also has a tendency to reduce the valve friction and the wear of the valve cage.

C. D. YOUNG,
Engineer of Tests.

Approved:
J. T. WALLIS,
General Supt. Motive Power.

Test Department,
Altoona, Penna.,
May 30, 1914.

PENNSYLVANIA RAILROAD COMPANY

Locomotive Testing Plant

AT

ALTOONA, PENNA.

BULLETIN No. 30

BRICK ARCH TESTS

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1916

LOCOMOTIVE TESTING PLANT.

TESTS OF A SOLID BRICK ARCH.

Conclusions on page 28.

INTRODUCTION.

1. It has been known that a very substantial economy in coal, an increase in power and other benefits are being derived from the very general use of the brick arch in the fireboxes of our locomotives. Trials of the arch on our modern locomotives have been lacking, however, and those here described were made to furnish a definite value for the solid sectional arch as a fuel-saving device and aid to increased locomotive capacity.

2. In 1907 tests were made with an Atlantic type locomotive to determine the merits of the hollow brick arch or one having air passages through the body of the arch for the purpose of heating and conveying air to the burning gases in the firebox. These tests, reported in Bulletin No. 6, showed that the use of such an arch, with a high volatile coal, would result in an economy in coal of from 12 to 13.5 per cent. Further, when the air inlets to the hollow arch were closed, the tests indicated that the hollow arch had no advantage over the arch of solid construction.

Description of Arch.

3. In the tests which have now been made a class L1s (2–8–2 or Mikado type) locomotive was used and it had a solid sectional brick arch supported upon four water tubes of 3 in. outside diameter, Fig. 1. The arch extended from the tube sheet 6 feet 4 inches or to a point 4 feet $4\frac{3}{4}$ inches from the rear water leg of the firebox. The minimum distance between the crown sheet and the top of the arch was $20\frac{3}{4}$ inches. The arch was

substantially the same as those in general use on our locomotives of this class as described in Bulletin No. 28. The locomotive had an exhaust nozzle of the four projections or partial bridge type, the area of which was equivalent to one of 7 in. diameter of the plain circular form.

The Tests.

4. Five tests, with the arch in place, were made under conditions of cut-off and speed as shown in the following table. These tests, while few in number, cover a wide range of the possible steam production of the boiler.

Tests with Arch.

Revolutions per Minute R.P.M.	Miles per Hour M.P.H.	Nominal Cut-off in Per Cent. of Stroke			
		30	50	60	65
80	14.5	1	1		
120	21.7		1	1	
160	28.9				1

Tests Without Arch.

5. There were six tests with the arch removed, but with the arch tubes still remaining in place in the firebox. The test conditions of these were as follows:

Revolutions per Minute R.P.M.	Miles per Hour M.P.H.	Nominal Cut-off in Per Cent of Stroke			
		30	50	60	65
80	14.5	1	1		
120	21.7		1	1	
160	28.9			1	1

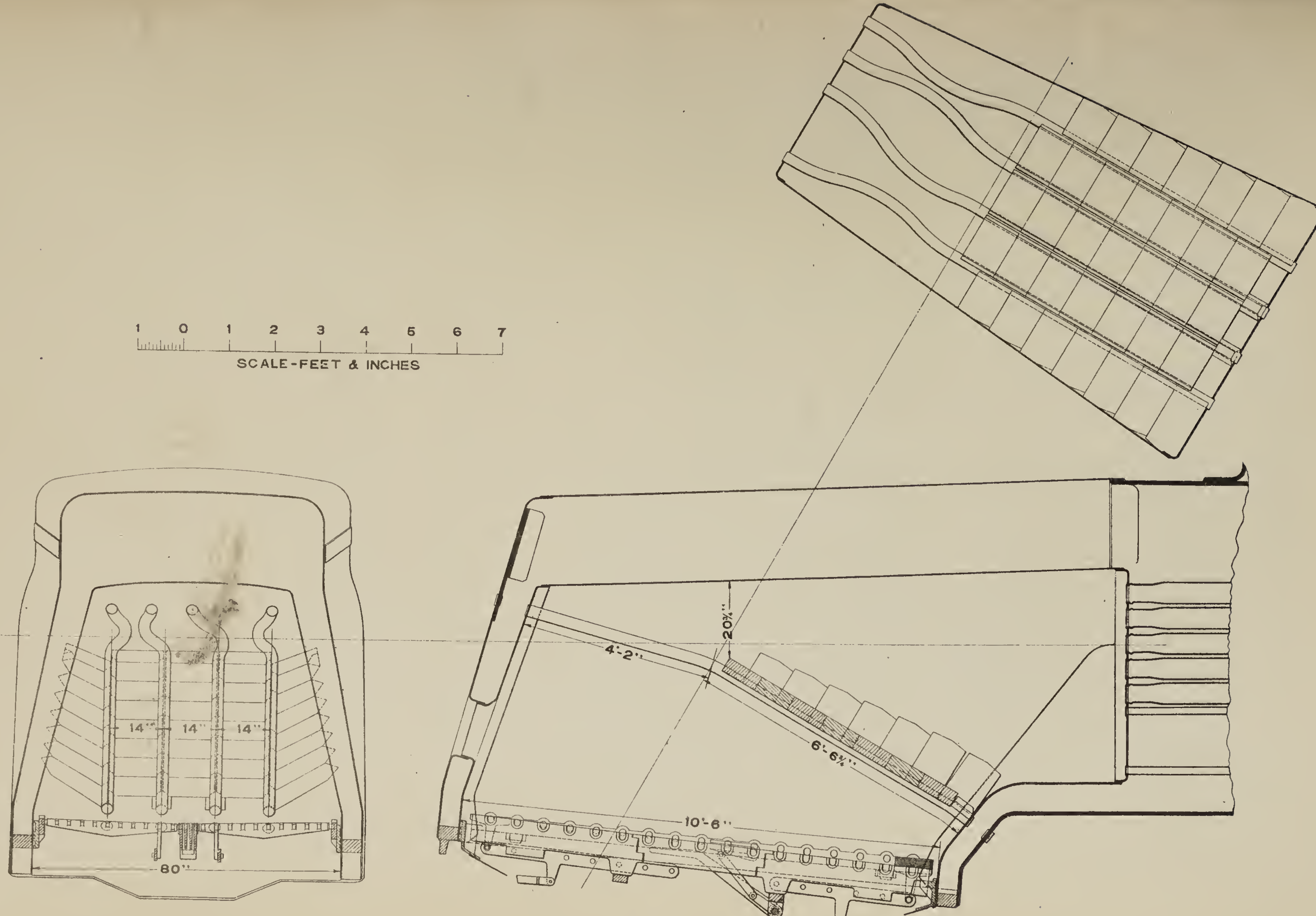

Fig. 1.
BRICK ARCH IN FIREBOX.

Sections of the firebox showing the arch as used in the tests. In the tests without arch the bricks were

Coal.

6. All of the tests were fired by hand with Jamison coal, which had passed over a screen having $1\frac{1}{4}$ in. openings. The two series of tests were fired with coal obtained from a single car.

Proximate Analysis of Coal Used in Tests.

Fixed carbon, per cent	54.00
Volatile matter, per cent	31.00
Moisture, per cent	0.92
Ash, per cent	14.08
Total	100.00
Sulphur, separately, per cent	1.14
Calorific value, B.t.u. per pound of combustible	15258
Calorific value, B.t.u. per pound of dry coal	13088

This is a Pennsylvania high volatile bituminous coal from the Latrobe region, Pittsburgh vein, and, except in being screened instead of run of mine, it is fairly representative of the coal used on our locomotives in freight service.

BOILER PERFORMANCE.

7. The results which are of particular interest pertaining to the boiler performance have been plotted in Figs. 2 to 11. The solid lines or curves represent the performance of the boiler with the arch and the dashed lines, with the arch bricks removed.

Draft.

8. The draft results do not show the velocity or volume of the gases flowing through the fuel bed and tubes, but they do show the intensity of the forces which produce the flow and an increased draft in inches of water indicates that there is a decreased area or an increase in the length of passage for the flow of the gases. The arch has the effect of increasing the length of passage of the combustible gases in the firebox and should give additional time for a thorough mixing of the gases and air, and their more complete combustion. It will be observed, Fig. 2, that the use of the arch caused an increase in the draft at like rates of combustion. This is especially noticeable at both front and back of diaphragm where the increases in draft are 25 and 30 per cent. respectively, when the rate of firing was 100 pounds of dry coal per square foot of grate per hour. Likewise, both in ashpan and firebox, an appreciable increase in draft with the arch occurs, especially at the high rates of combustion.

9. There is also shown an increase in draft at all rates of equivalent evaporation per square foot of heating surface, Fig. 3. An increased draft or vacuum is to be expected from the use of the arch, as it presents a form of obstruction in the gas passages in the firebox.

Firebox and Smokebox Temperatures.

10. The firebox temperature is increased by the presence of the arch as shown by Fig. 4. With the arch the temperature is between 2400 and 2800 degrees while without the arch it is from 2100 to 2600 degrees, the temperatures increasing in both cases with increases in the rate of firing. The firebox conditions are reflected in the smokebox temperatures where the arch tests show temperatures slightly higher than those without arch.

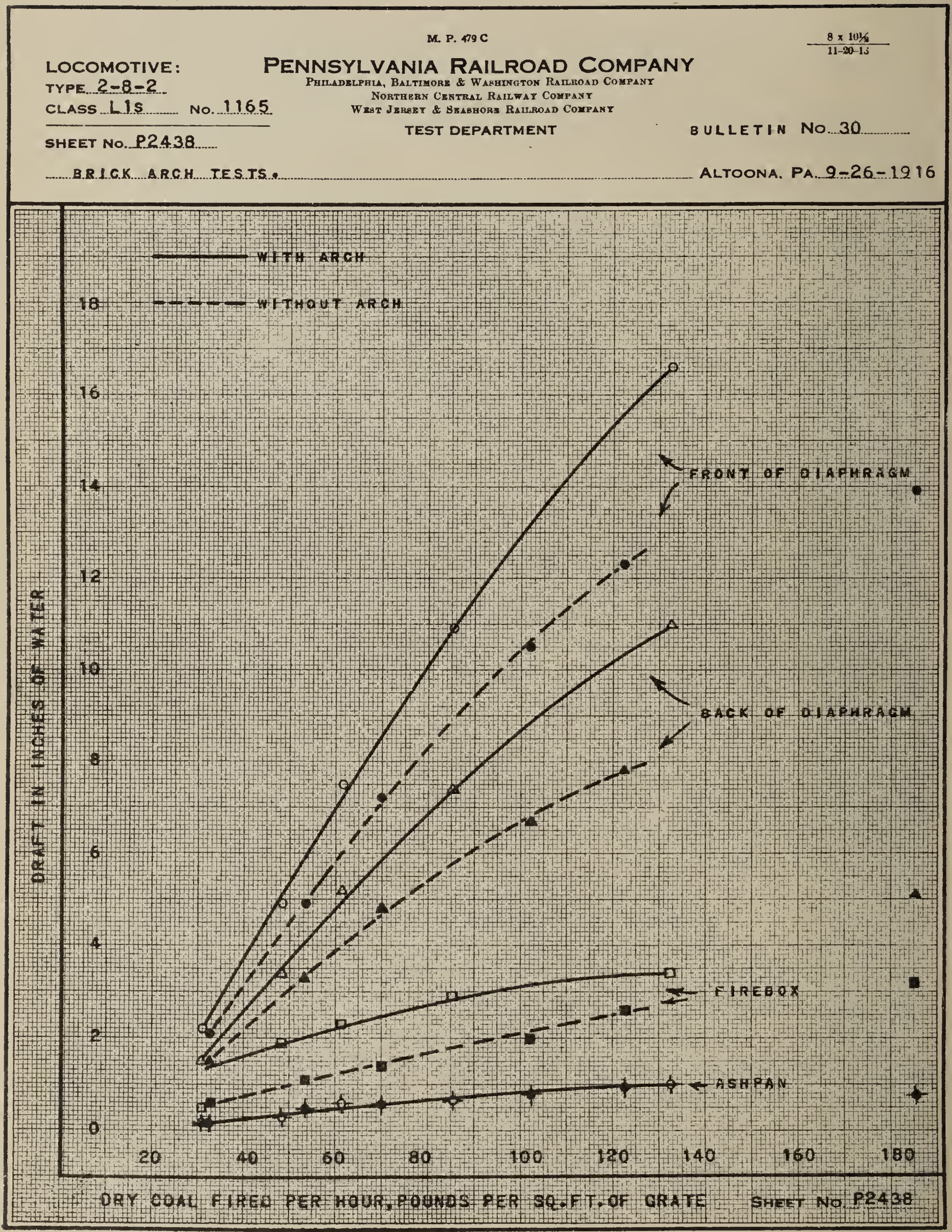

Fig. 2.

DRAFT AND RATE OF COMBUSTION.

The resistance offered by the arch causes an increase in the draft intensity at all points.

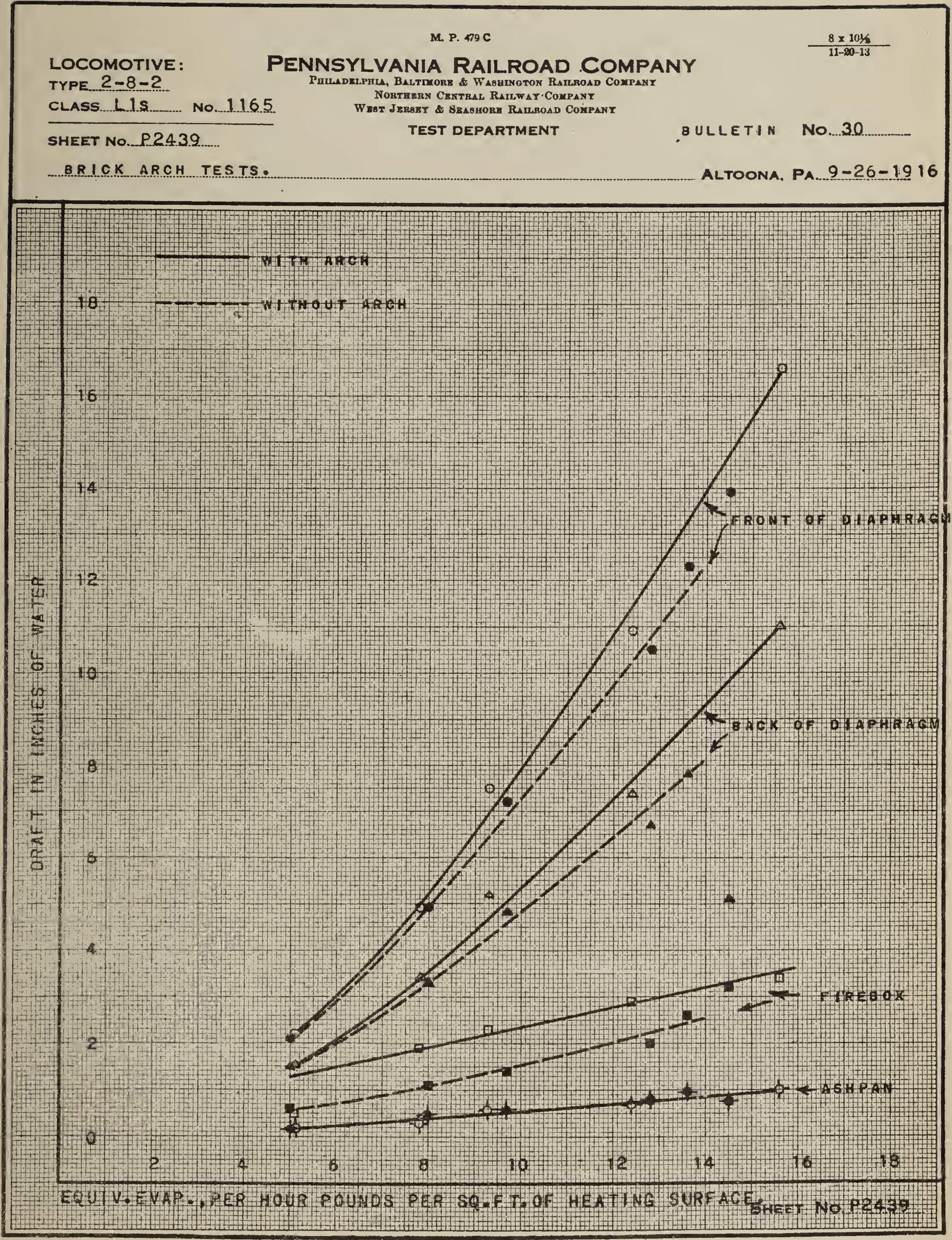

Fig. 3.

DRAFT AND RATE OF EVAPORATION.

The draft or partial vacuum is increased by the use of the arch.

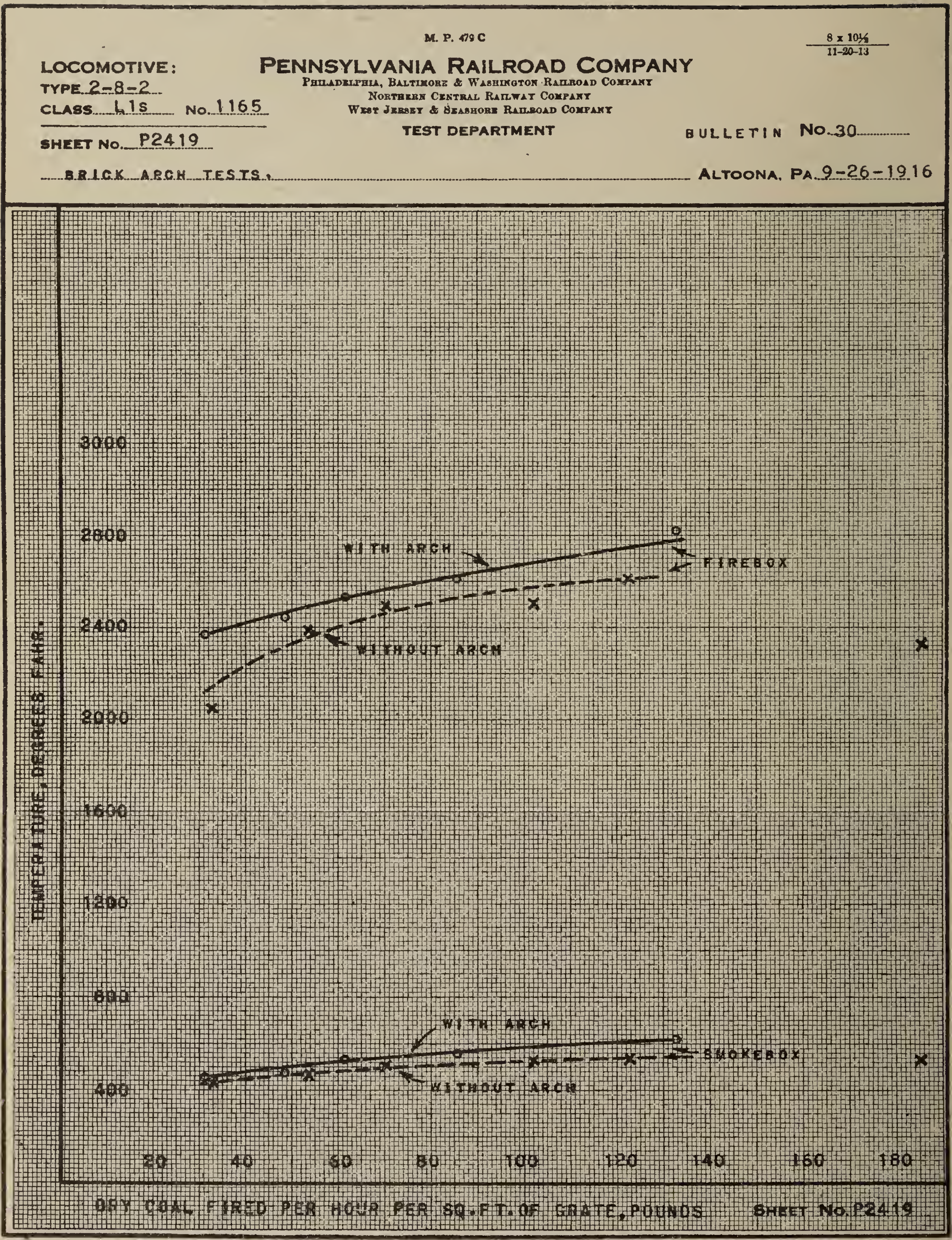

Fig. 4.

FIREBOX AND SMOKEBOX TEMPERATURES.

The firebox and smokebox temperatures are increased by the use of the arch.

Evaporation.

11. The effect of the arch upon the evaporation of the L1s boiler is illustrated in Fig. 5. It is here shown that the brick arch is responsible for an increase in evaporation at all rates of combustion. In road service these locomotives would not often be fired at a rate above 5600 pounds per hour and at this rate the increase in evaporation is 8.5 per cent. Further, it may be observed that the arch was responsible for an increase in boiler capacity, for the maximum evaporation with a good boiler pressure was 15.5 per cent. greater than that obtained without the arch. In a number of the diagrams a point is shown for a test without arch but the test is not taken into account in drawing the curve for tests without arch. This test, No. 5015 at 160–65–F, was made by driving the boiler far beyond its true capacity, without the arch, and by firing coal at the rate of 13,000 pounds per hour. The evaporation, under these conditions was 53,800 pounds per hour and the boiler pressure 185 pounds. A greater evaporation, 58,200, with the arch, was obtained with a rate of firing of 9300 pounds per hour and a boiler pressure of 204.3 pounds. Test No. 5015 is of interest in showing the waste of coal when an attempt is made to obtain high boiler capacity without the arch.

Smoke.

12. A decrease in the smoke density or blackness, Fig. 6, accompanied the use of the arch at all rates of combustion.

Equivalent Evaporation.

13. An improved equivalent evaporation per pound of dry coal, Fig. 7, was obtained at all rates of firing with the use of the arch, indicating an economy ranging from 6 to 10 per cent. as the firing rate increased from minimum to maximum. If the maximum rate of firing in road service is 80 pounds per square foot of grate or 5600 pounds per hour the saving due to the arch is between 6 and 8 per cent. At like rates of equivalent evaporation per square foot of heating surface, Fig. 8, the arch effected an increase in the evaporation per pound of dry coal ranging between 7.4 and 18 per cent. as the evaporation per square foot of heating surface was increased from 5 to 14 pounds. When considering the rates of evaporation which occur in service or those between 6 and 12 pounds per square foot of heating surface the saving due to the arch is between 7.4 and 12.4 per cent.

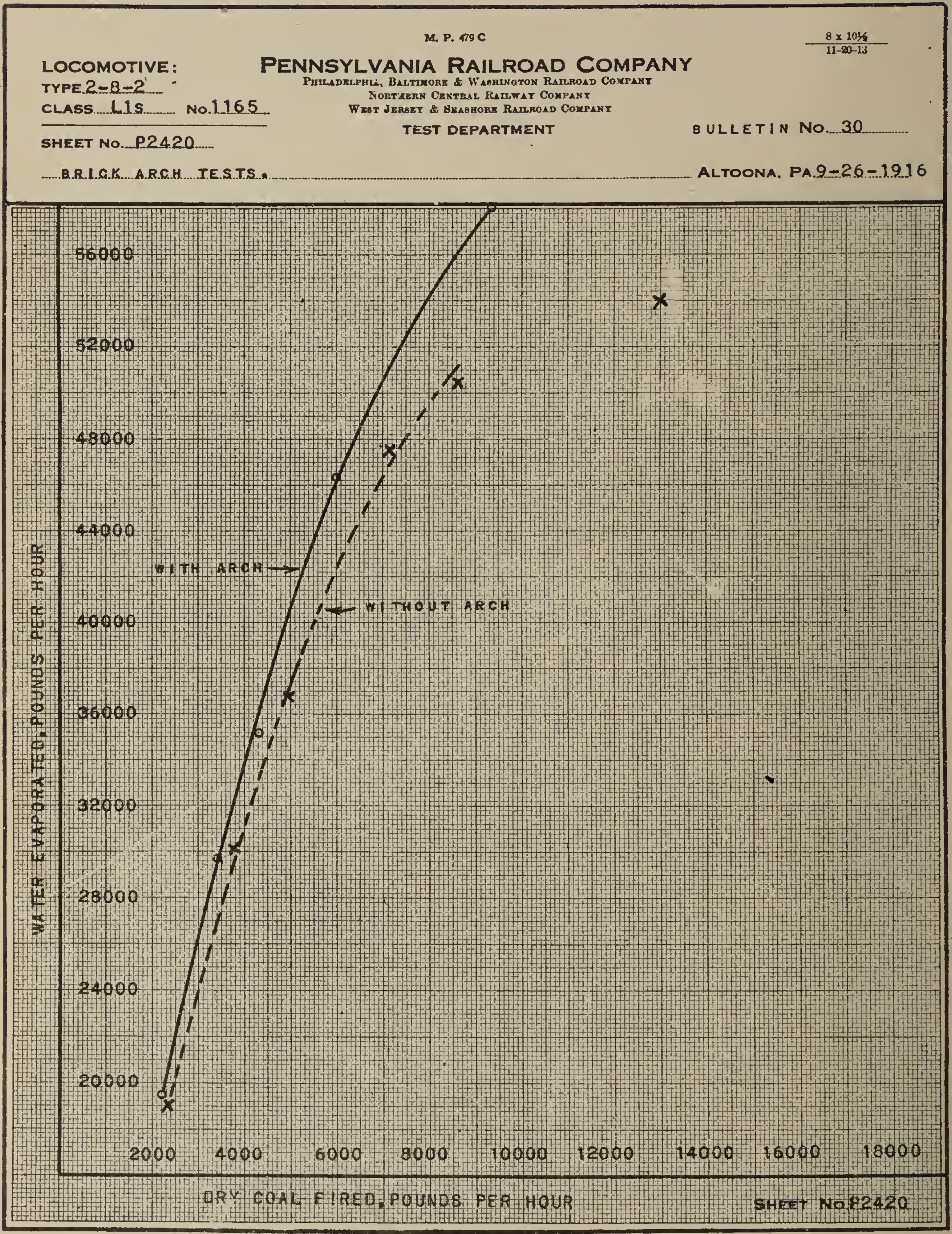

Fig. 5.

COAL FIRED AND WATER EVAPORATED.

With the arch the evaporation is greater than without the arch at all rates of firing. The increase in maximum evaporation is about 15.5 per cent.

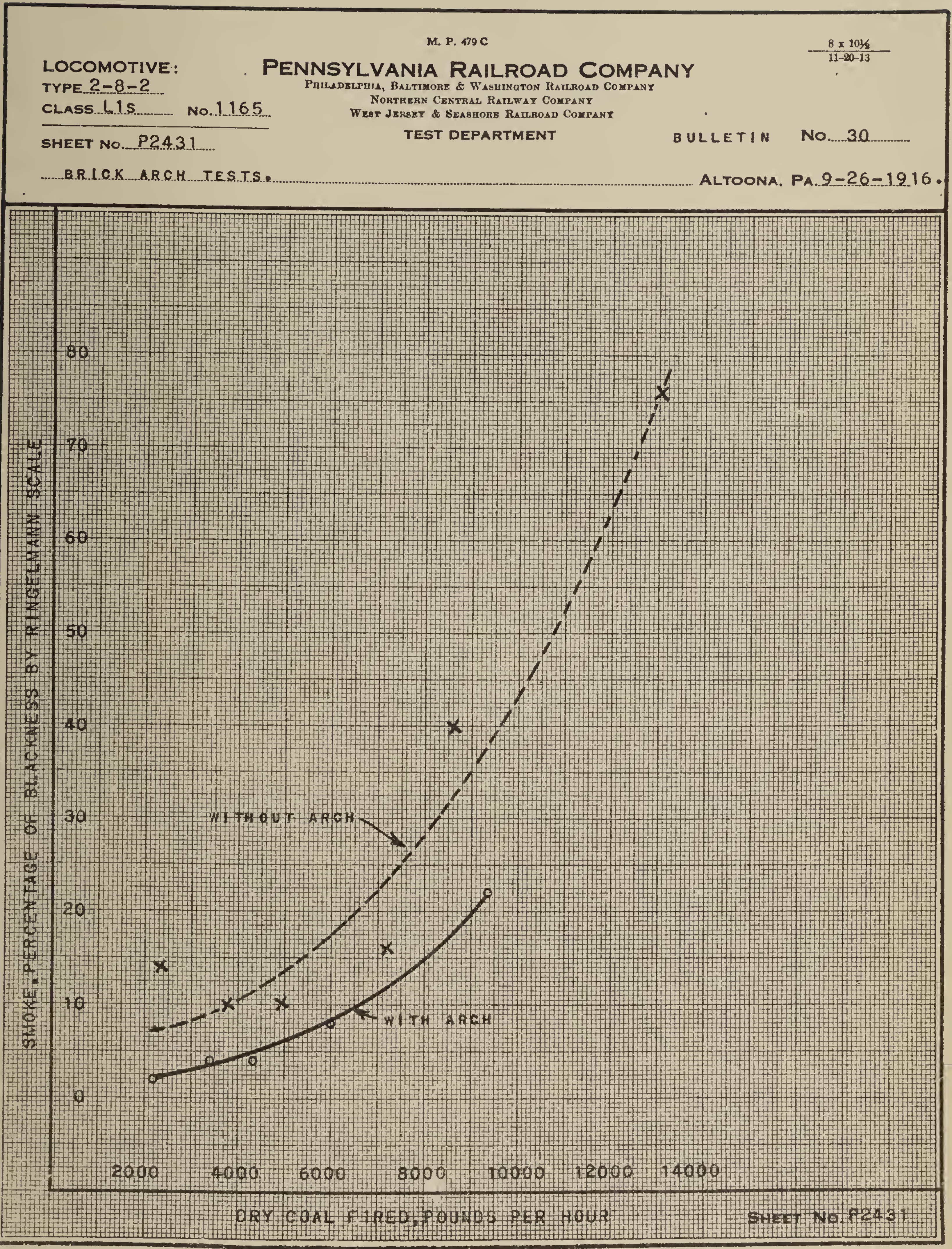

Fig. 6.

COAL FIRED AND SMOKE.

With this coal there appears to be less smoke with than without arch.

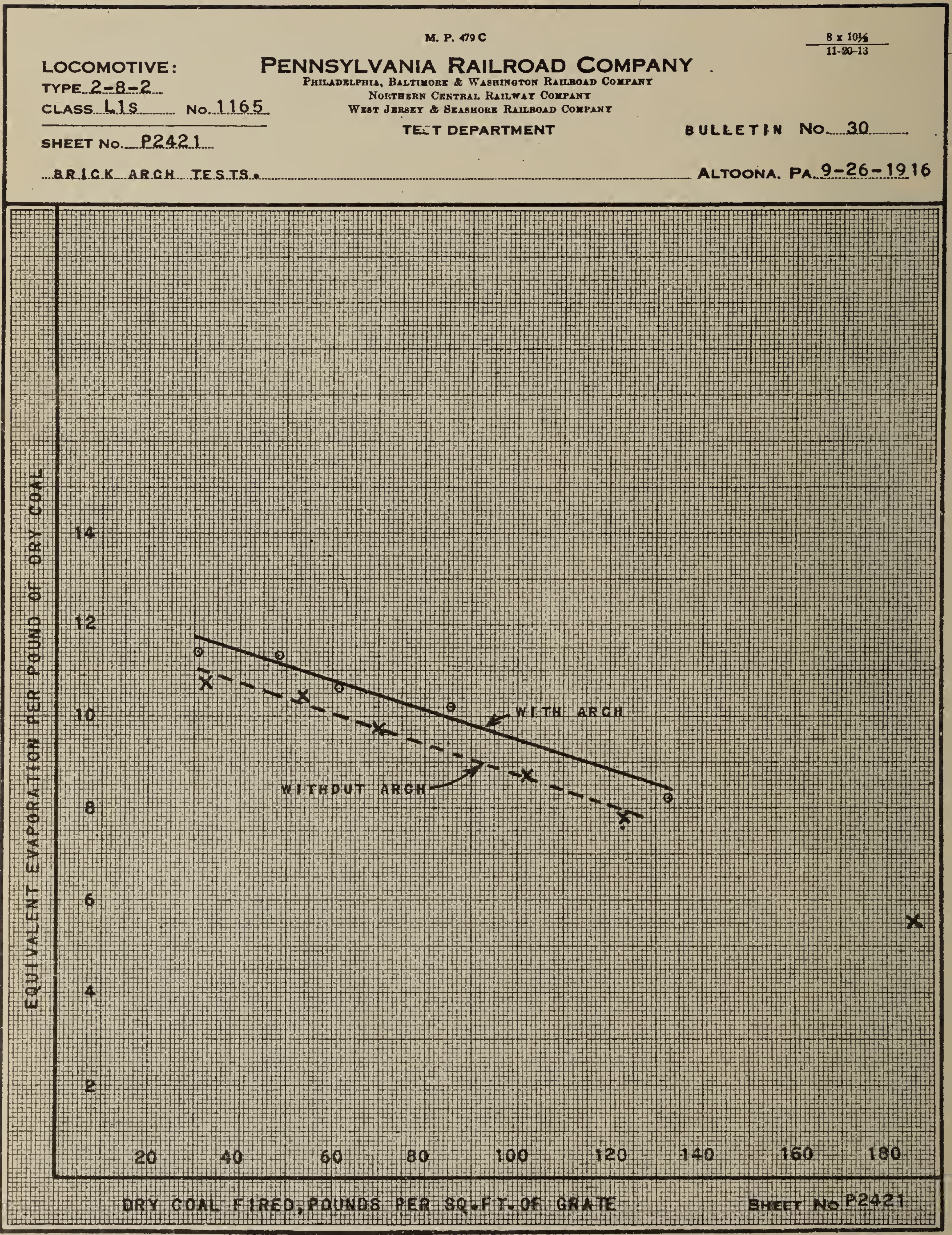

Fig. 7.

RATE OF FIRING AND EVAPORATION PER POUND OF COAL.

With this high volatile coal the arch shows an increase in equivalent evaporation per pound of coal of about 8 per cent.

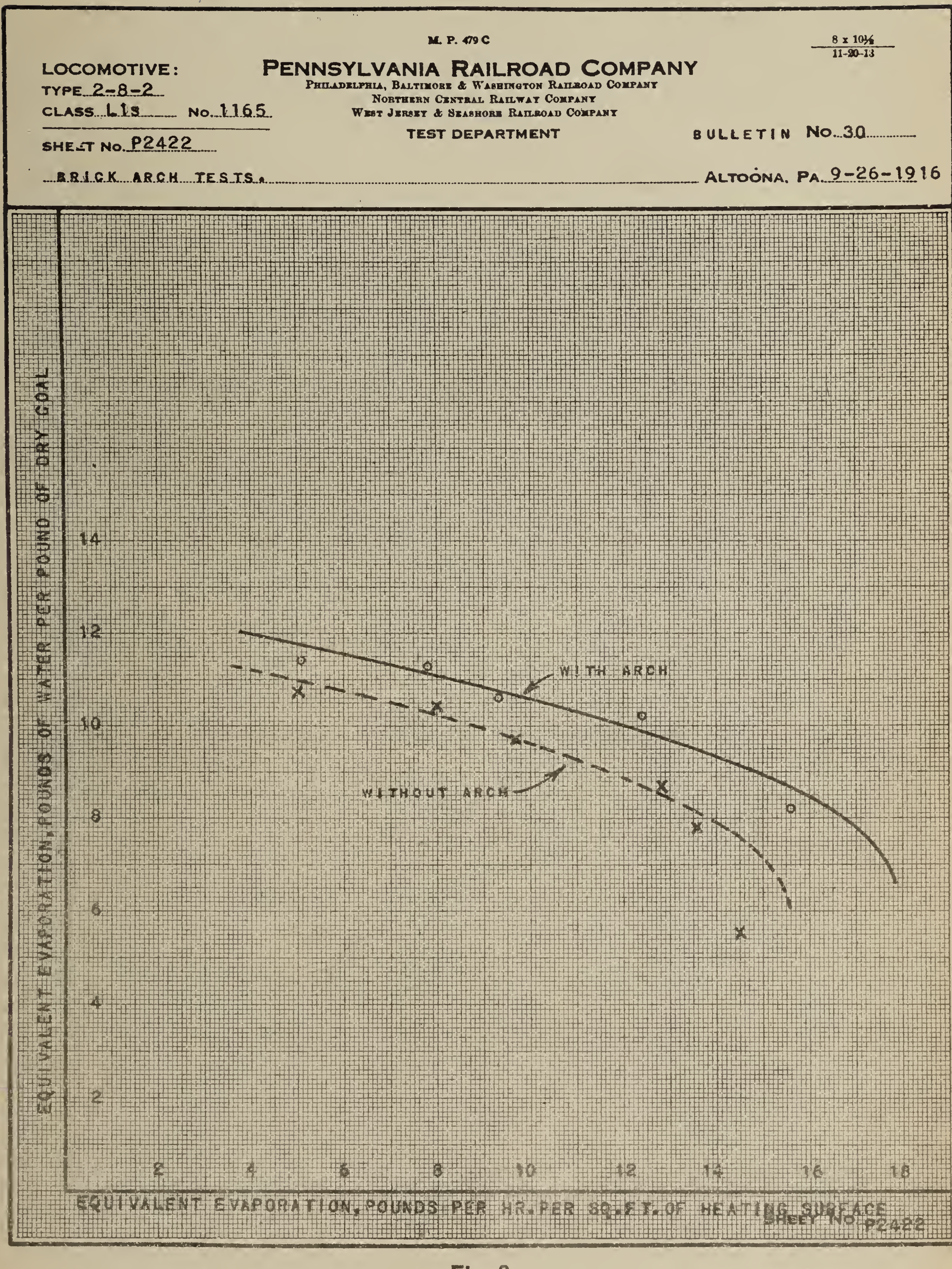

Fig. 8.

RATE OF EVAPORATION AND EVAPORATION PER POUND OF COAL.

When the test results are plotted according to the rate of evaporation the increase in evaporation per pound of coal due to the arch, is about 10 per cent.

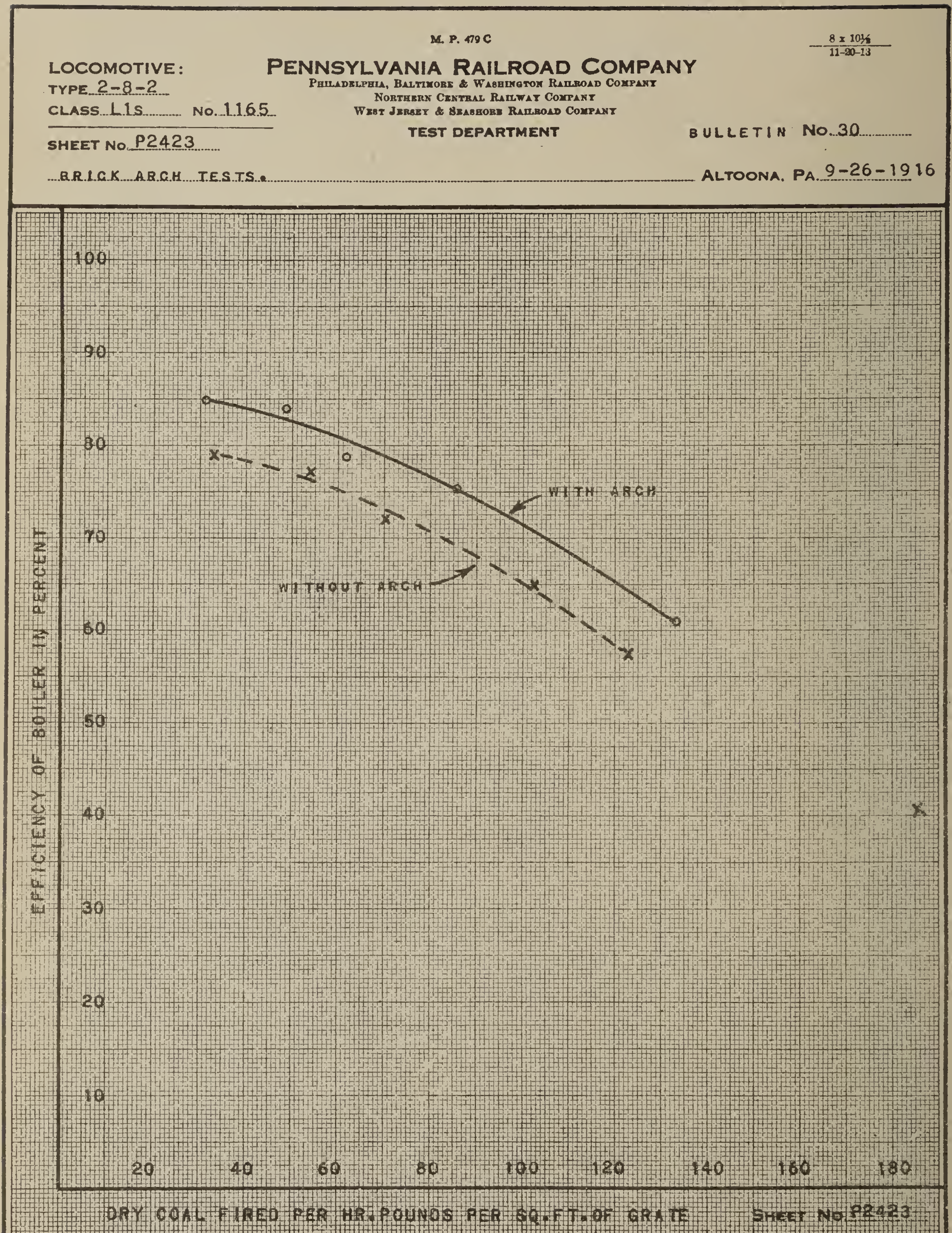

Fig. 9.

RATE OF FIRING AND EFFICIENCY OF BOILER.

With the arch there is a uniformly higher efficiency of the boiler.

Boiler Efficiency.

14. When plotted against the combustion rate, Fig. 9, the boiler efficiency shows an increase ranging between 6.9 and 11.6 per cent. as the rate of firing increased from 35 to 120 pounds of dry coal per square foot of grate per hour. Here again if we consider the rates which occur in service the increase in boiler efficiency would be between 7 and $8\frac{1}{2}$ per cent. When compared on the basis of water evaporated per hour as in Fig. 10 the arch shows a higher boiler efficiency at all rates of evaporation. Other experimenters have found that the arch tubes alone by their added heating surface and the increase in the circulation of water in the boiler, cause a saving of approximately one per cent. for each tube. It may be assumed, then, that our boiler when operated without the arch, but with the four arch tubes in the firebox, gave an evaporation that was some four or five per cent. better than would have been the case had the arch tubes been removed.

ENGINE PERFORMANCE.

15. The use of the brick arch has no direct effect upon the engine economy but results in an increase in cylinder horsepower on account of the greater evaporation.

16. It is interesting to note that no higher superheat, as shown in Fig. 11, was obtained with the arch and as a consequence no improvement in the weight of steam per horsepower is to be expected from the use of the arch. Fig. 12 confirms this as the results with and without arch are of about equal value at all powers.

17. The maximum indicated horsepower obtained with the arch in use was 2790.3 at 28.9 m.p.h. and 65 per cent. cut-off, while with the arch removed but 2602.8 i.h.p. was developed at this speed but with a 60 per cent. cut-off, thus showing an increase in power of 7.2 per cent. in favor of the arch.

18. The economy in coal, based on the indicated horsepower developed, Fig. 13, increases with the power and ranges from 0 at light loads to 12 per cent. at maximum power.

19. It is noticeable, Fig. 14, that an increase in cylinder horsepower is obtained, when using the arch, at all rates of combustion. This increase varies, and, as we have shown in Par. 17, it is about 7.2 per cent. when firing 9500 pounds of coal per hour.

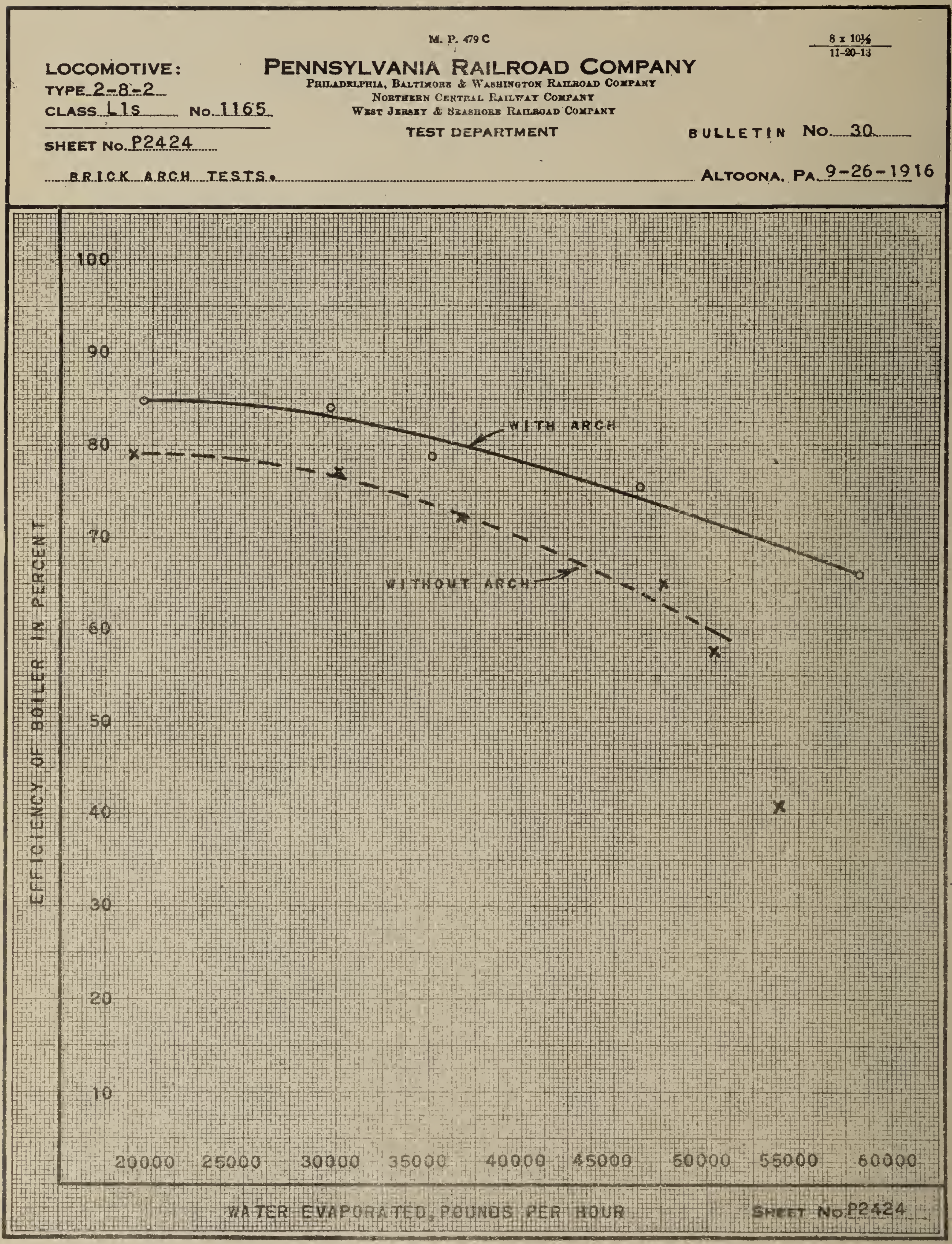

Fig. 10.

EVAPORATION AND BOILER EFFICIENCY.

With the arch the boiler efficiency is increased at all rates of evaporation.

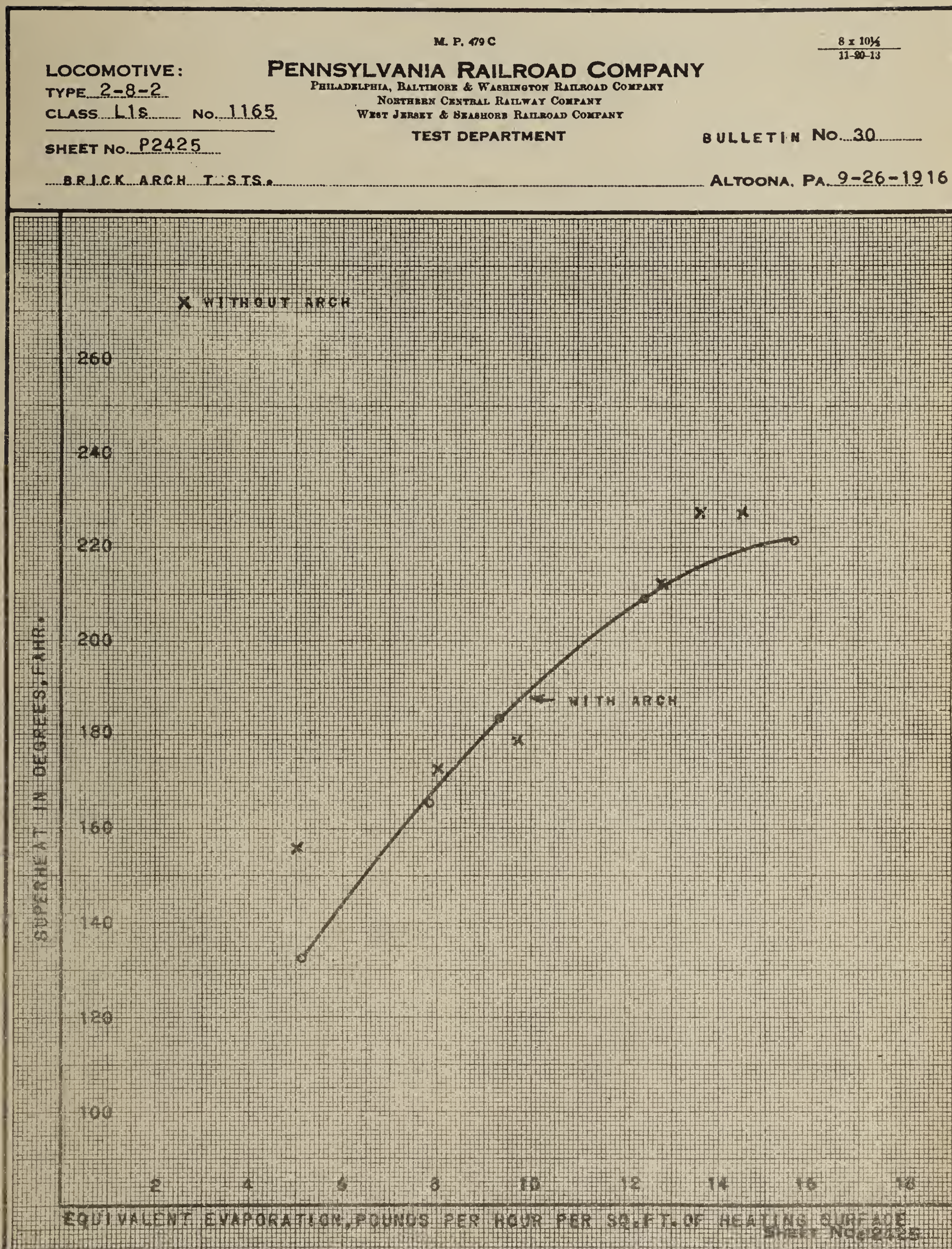

Fig. 11.

RATE OF EVAPORATION AND SUPERHEAT OF STEAM.

The superheat of the steam is not increased by the use of the arch.

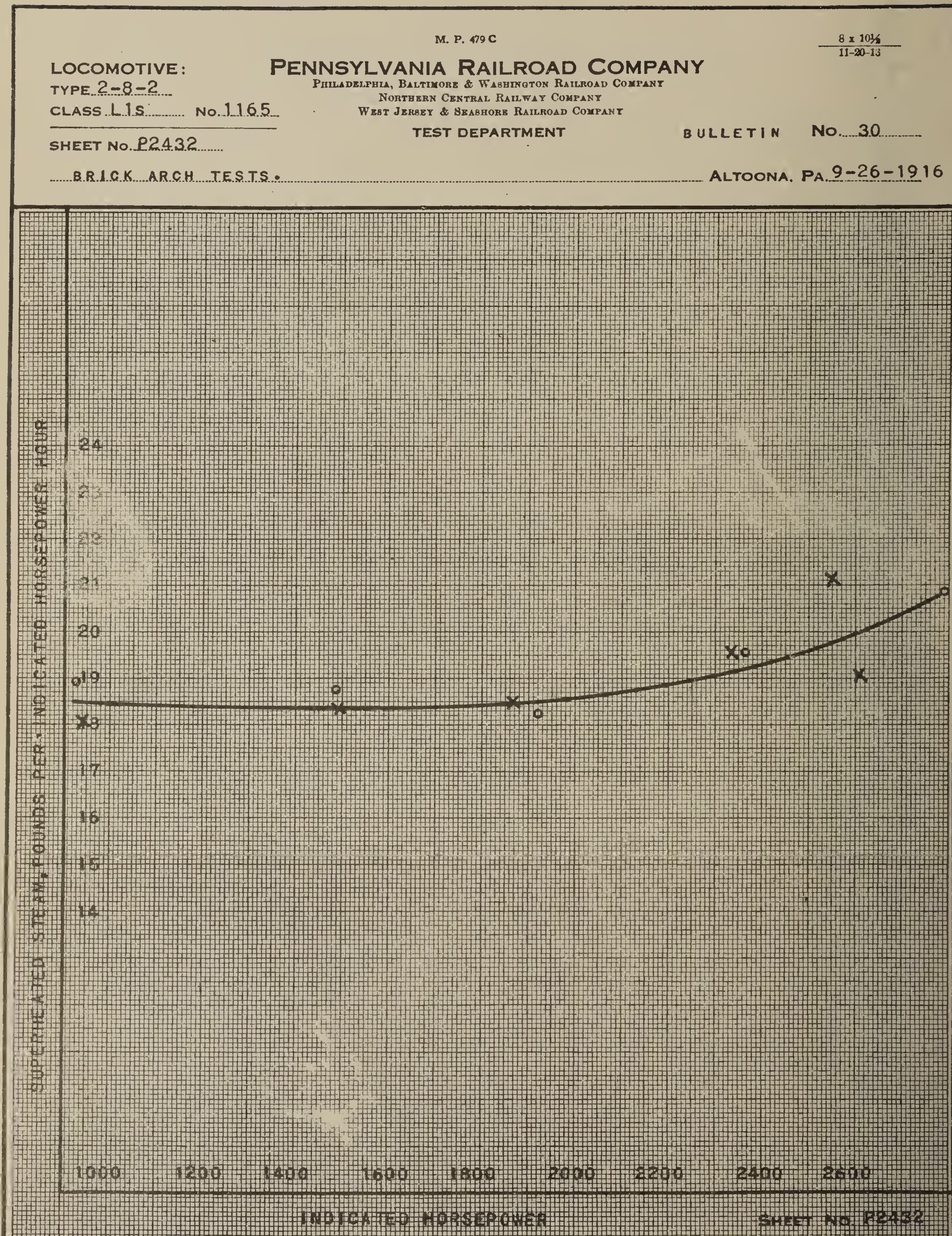

Fig. 12.

INDICATED HORSEPOWER AND WATER RATE.

The superheat is not changed by the use of the arch and the water rate remains the same as without the arch.

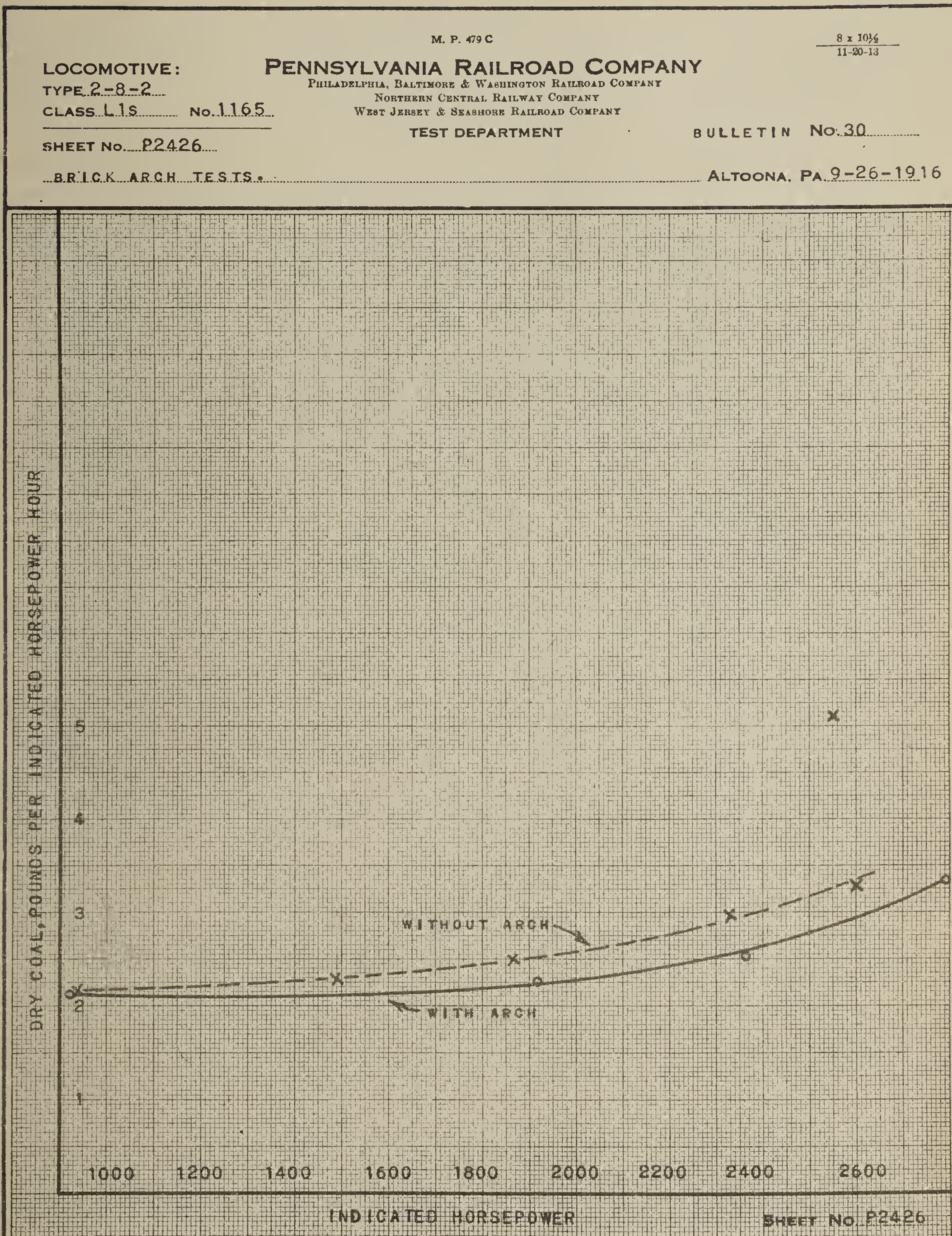

Fig. 13.
INDICATED HORSEPOWER AND COAL RATE.
About 6 per cent. of the coal, on the average, is saved by the use of the arch.

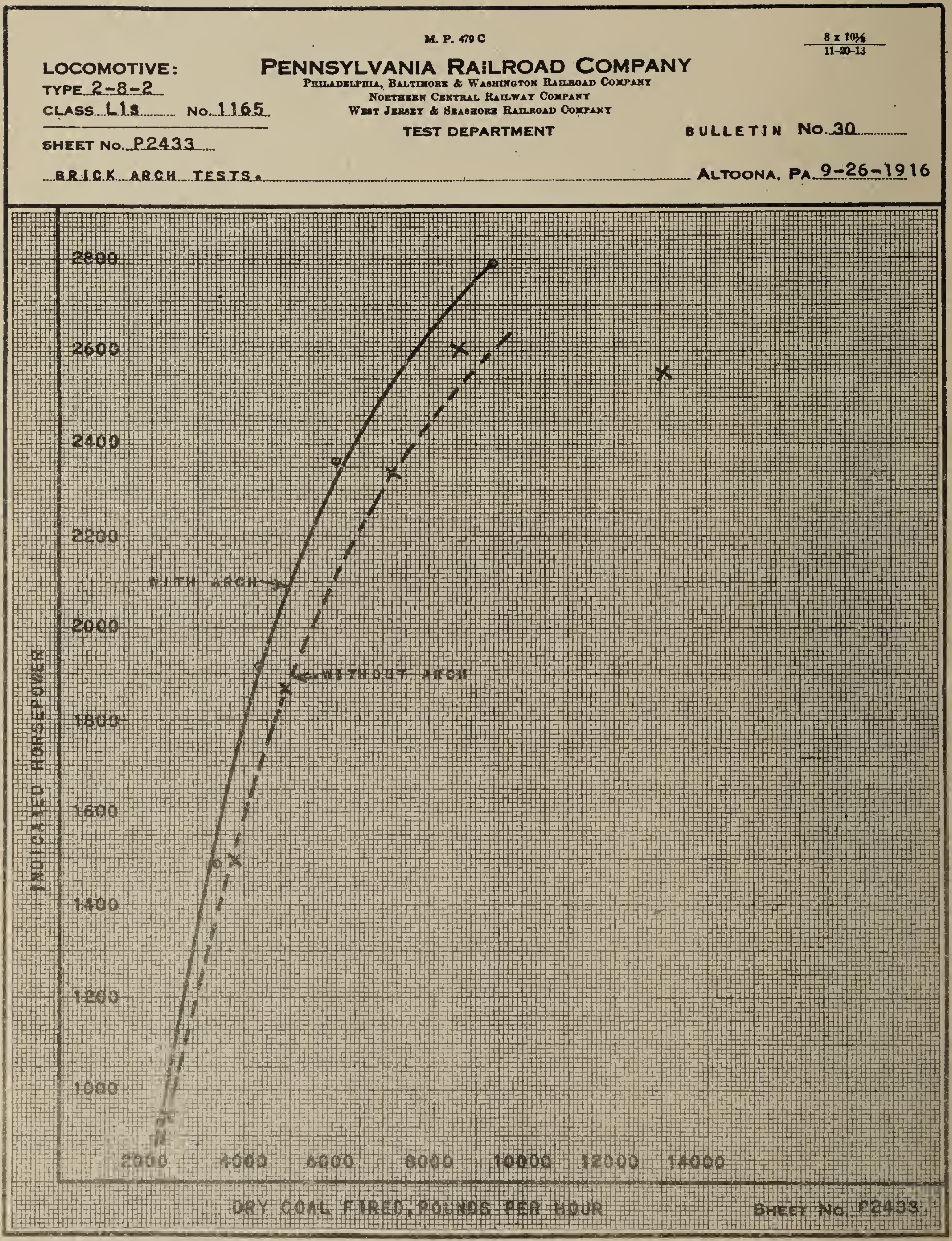

Fig. 14.

COAL FIRED AND INDICATED HORSEPOWER.

At all powers, less coal is required with the arch.

LOCOMOTIVE PERFORMANCE.

20. The dynamometer records indicate that the effect of the arch upon the locomotive is twofold, it decreases the coal per dynamometer horsepower, and by reason of the increased boiler capacity, it produces an increased dynamometer horsepower, resulting in a greater drawbar pull at speeds above 8 miles per hour.

21. The steam used per dynamometer horsepower hour, Fig. 15, is not affected by the use of the arch.

22. The increase in dynamometer horsepower at the maximum power developed is 6.4 per cent. in favor of the arch. This increase was obtained at a speed of 28.9 m.p.h. and a cut-off of 65 per cent.

23. The economy in coal, Fig. 16, in favor of the arch, is between 6 and 18 per cent. or an average of about 12 per cent.

24. This economy in coal, based on the dynamometer horsepower output, makes possible an increase in dynamometer horsepower at all rates of combustion. Fig. 17 illustrates this fact clearly, showing that the locomotive with the brick arch could develop 17.0 per cent. more dynamometer horsepower at 4000 pounds, and 7.2 per cent. more when the firing rate approximates 9500 pounds of dry coal per hour.

25. The additional power developed with the arch in use, as shown in Fig. 17, makes possible an increase in drawbar pull at speeds above 8 miles per hour, Fig. 18, where the increased capacity of the boiler is an important factor. An increased pull of 6.4 per cent. was obtained at 29 m.p.h.

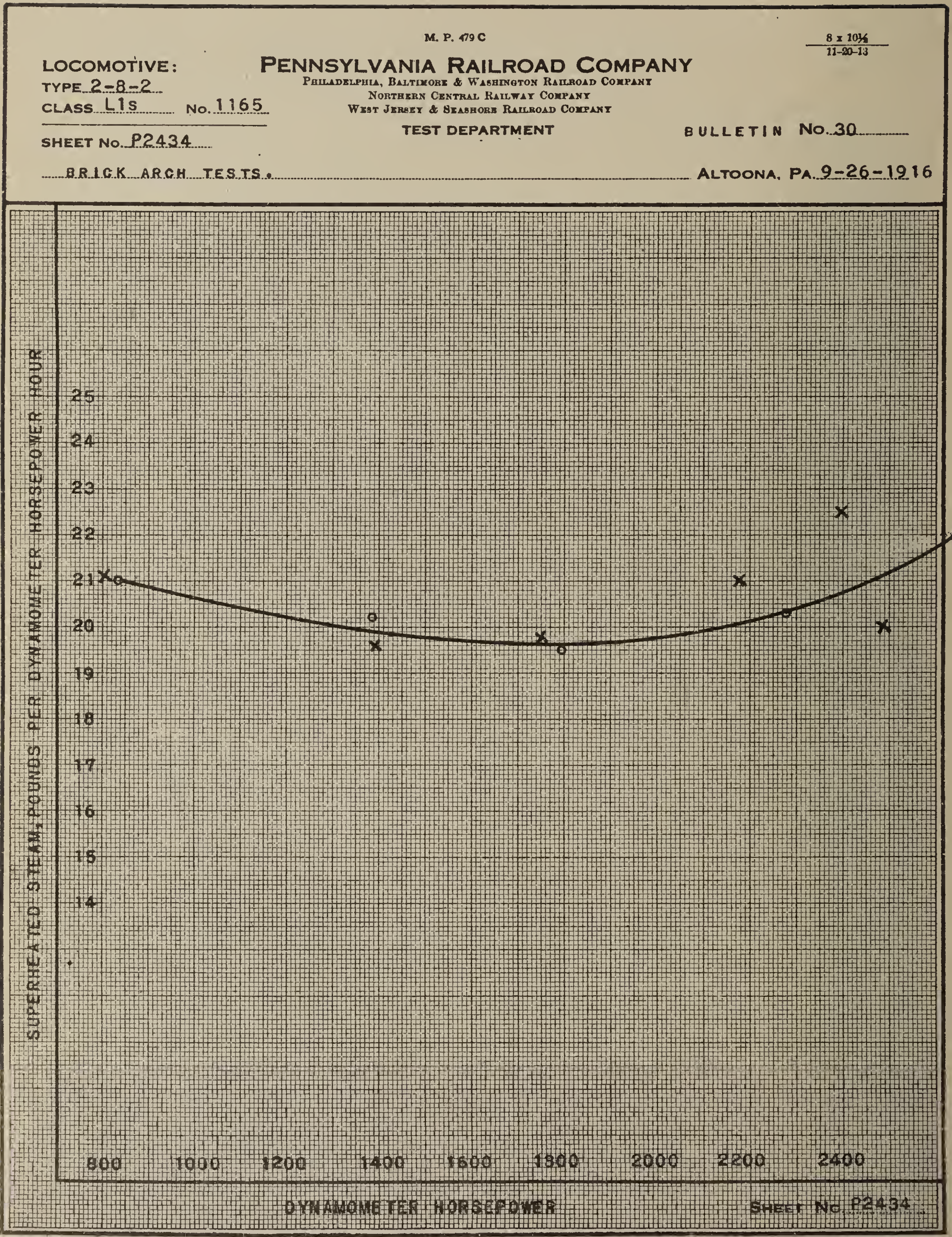

Fig. 15.

DYNAMOMETER HORSEPOWER AND WATER RATE.

There is no difference shown between the results with and without the arch.

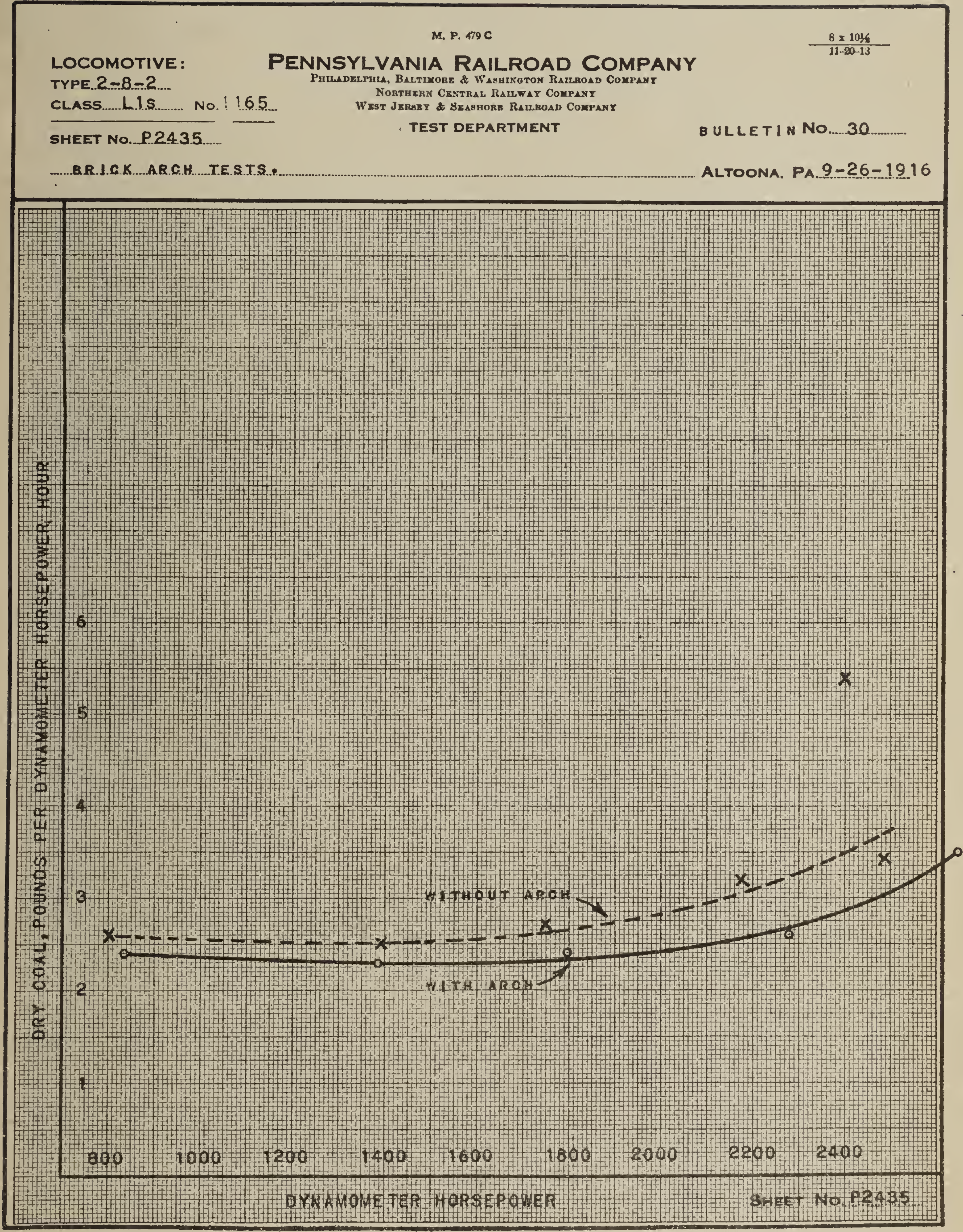

Fig. 16.

DYNAMOMETER HORSEPOWER AND COAL RATE.

At all horsepowers there is a saving of coal with the arch.

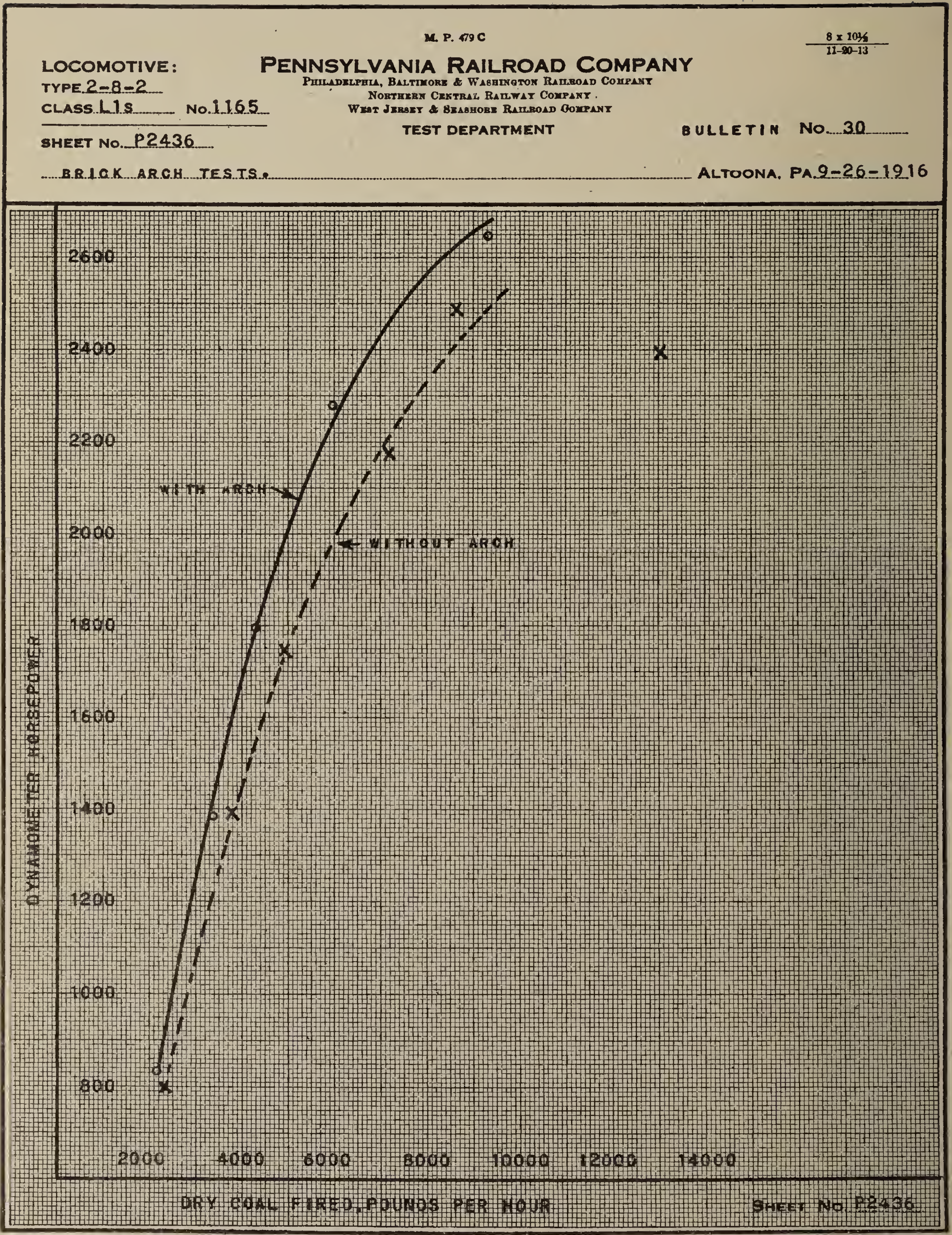

Fig. 17.
COAL FIRED AND DYNAMOMETER HORSEPOWER.
At all dynamometer horsepowers less coal is required with the arch.

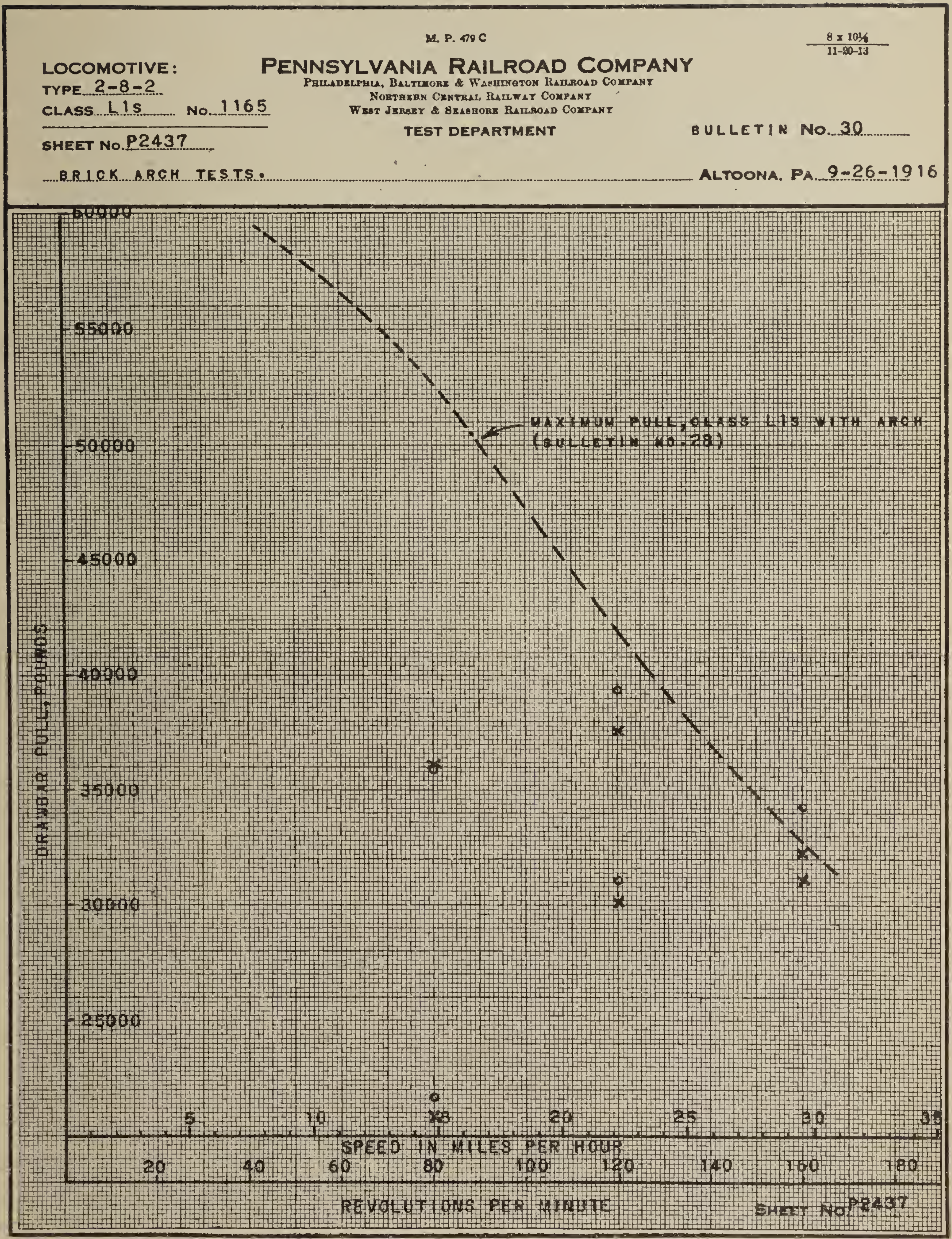

Fig. 18.

SPEED AND DRAWBAR PULL.

The maximum pull is developed at one speed only, 29 miles per hour, and at this speed, the test with arch, shows a pull of 34,284 pounds, while without the arch the pull is 32,218 pounds. The difference is 2066 pounds or an increase of 6.4 per cent. with the arch.

CONCLUSIONS.

Boiler.

The results of these tests point to the following facts favorable to the use of the solid brick arch, the advantage of which in coal saving, as shown by these tests, is due in a large measure, to the use of a high volatile gas coal which has a long flame and requires, for its proper combustion, an increase over the usual distance between the fuel bed and the tube openings. The low volatile coals do not require this long flameway and their combustion is not benefited by the arch to nearly the same extent as that of the high volatile coals.

(*a*) The maximum evaporation when using high volatile coal was increased 15.5 per cent. by the use of the arch, thus indicating a larger boiler capacity. (Par. 11.)

(*b*) There occurs with the arch a lower smoke density as measured by the Ringlemann scale. (Par. 12), which coincides with the conclusions from earlier arch tests (see first part of Par. 29, Bulletin 6.)

(*c*) The arch increases the evaporation per pound of coal and for ordinary rates of working this increased evaporation represents an economy in coal of from 6 to 8 per cent. (Par. 13.) This is similar to the results obtained in previous arch tests where an economy of from 12 to 13½ per cent. was obtained (see Par. 26, Bulletin 6.)

(*d*) A higher boiler efficiency was made possible by the arch at all rates of evaporation. (Par. 14.)

Engines.

(*a*) The coal saving due to the arch ranged between 0 and 12.0 per cent. (Par. 18.)

(*b*) The cylinder or indicated horsepower was increased 7.2 per cent. (Par. 17.)

Locomotive.

(*a*) An increase in the maximum dynamometer horsepower was obtained amounting to 6.4 per cent. (Par. 22.)

(*b*) At equal combustion rates an increase in dynamometer horsepower is possible, ranging between 17.0 per cent. at the 4000-pound rate and 7.2 per cent. at the 9500-pound rate of firing. (Par. 24.)

(*c*) The increased capacity of the boiler and the additional cylinder power of the engines make possible an increased drawbar pull at speeds above 8 m.p.h. The increase in pull at 29 m.p.h. was 6.4 per cent. (Par. 25.)

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
General Supt. Motive Power.

TEST DEPARTMENT,
ALTOONA, PENNA.,
December 30, 1916.

M. P. 394A
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

BULLETIN NO. 30

TEST DEPARTMENT

Average Results of Locomotive Tests

LOCOMOTIVE:
TYPE 2-8-2
CLASS L1s
NUMBER 1165

TEST NOS. 5006 TO 5010
5012 TO 5017

SUBJECT: BRICK ARCH TESTS.

ALTOONA, PA., 9-26-1916

No.	Item	Value
	Driving Wheels	
1	Number of Pairs	4
2	Approx. Diameter, inches	62
	Engine Truck Wheels	
14	Number	2
15	Diameter, inches	33
	Trailing Wheels	
16	Diameter, inches	49.85
	Wheel Base, Feet	
17	Driving Wheel Base	17.04
18	Total Wheel Base	36.40
19	Gage of Wheels	56.00
	Weight of Engine with Water at 2d. Gage Cock and Normal Fire, Pounds	
20	On Truck	27200
21	" 1st Drivers	55900
22	" 2d "	56400
23	" 3d "	62000
24	" 4th "	61500
25	" 5th "	
26	" Trailers	52600
27	Total	315600
28	" on Drivers	235800
	Cylinders	
	Diam. and Stroke, H. P.	27 x 30
	" " " L. P.	-
	Clearance in Per Cent. of Piston Displacement	
40	H. P. Right, Head End	8.30
41	" " Crank "	6.89
42	" Left, Head "	8.56
43	" " Crank "	7.15
44	L. P. Right, Head "	-
45	" " Crank "	-
46	" Left, Head "	-
47	" " Crank "	-
	Receiver, Cubic Feet	
48	Volume Right Side	-
49	" Left "	-
	Steam Ports, Inches	
50	H. P. Admission, Length	29.94
51	" " Width	2.25
58	L. P. " Length	-
59	" " Width	-
66	H. P. Exhaust, Length	-
67	" " Width	-
70	L. P. " Length	-
71	" " Width	-

No.	Item	Value
	Piston Rods, Diameter Inches	
74	High Pressure	4.328
76	Low "	-
	Tail Rods, Diameter, Inches	
78	High Pressure	3.452
80	Low "	
	Valves	
82	Type	12 INCH PISTON
83	Design	ANCHORED L RING
84	Per Cent. Balanced	100
85	Type of Valve Motion	WALSCHAERTS
	Greatest Valve Travel	
86	High Pressure, inches	6
88	Low " "	-
	Steam Lap of Valve	
90	High Pressure, inches	0.89
94	Low " "	-
	Exhaust Lap of Valve	
98	High Pressure, inches	0.13
102	Low " "	
	Boiler	
113	Type	BELPAIRE WIDE F.B
114	Outside Diam. 1st Ring	82.05
	Tubes	
115	Number	LARGE 40 SMALL 236
116	Outside Diam., inches	$5\frac{1}{2}$ AND $2\frac{1}{4}$
	Pitch "	
118	Length Between Tube Sheets, inches	227.0
119	Total Fire Area, sq. ft.	8.41
124	Boiler Pressure, pounds	205
	Superheater	
125	Number of Tubes	40
126	Outside Diam. " inches	1.5
128	Length of " "	217.0
	Firebox, Inside, Inches	
132	Length	170.69
133	Width	75.96
137	Air Inlets to Ashpan, sq. ft.	7.85
	Grates	
144	Type	
145	Grate Area, sq. ft.	70.27
146	Area of Dead Grates	0.0

No.	Item	Value
	Heating Surface, Square Feet	
154	Of the Tubes, Water Side	3713.79
155	" " " Fire "	3372.00
156	" " Firebox, " "	305.97
157	" " Superh'r, " "	1233.24
*158	Total, Based on " "	4911.21
159	" " " " " of Firebox and Water Side of Tubes	5253.00
	Boiler Volume with Water Surface at Level of 2d Gage Cock	
160	Water Space, cu. ft.	1572.06
161	Steam " " "	127.73
	Exhaust Nozzle	
162	Double or Single	SINGLE
163	Size, inches	7 INCH
167	Area, sq. inches	38.19
	Reverse Lever	
168	H. P. Notches Forward of Center	49
169	L. P. Notches Forward of Center	-
	Ratios	
171	Heating Surface (158) to Grate Area (145)	69.00
172	Fire Area Thru Tubes (119) to Grate Area (145)	0.12
173	Firebox Heating Surface (156) to Grate Area (145)	4.35
174	Tube Heating Surface (155) to Fire Box Heating Surface (156)	11.02

LOCOMOTIVE HAS:- SCHMIDT SUPERHEATER, SECURITY SECTIONAL ARCH, FOUR PROJECTION NOZZLE TIP.

*USED IN CALCULATIONS

Table I.
DIMENSIONS OF LOCOMOTIVE.

M. P. 394 A—Second Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

Bulletin No.30

LOCOMOTIVE:
TYPE 2-8-2
CLASS L1s
NUMBER 1165

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Brick Arch Tests. ALTOONA, PA., 9-26-1916

TEST NUMBER	RUNNING CONDITIONS									BOILER PERFORMANCE — TEMPERATURE, DEGREES F.			
	TEST DESIGNATION	Date of Test	Duration of Test Hours	Revolutions per Minute	Speed in Miles per Hour	Piston Speed in Feet per Minute	Reverse Lever, Notches from Front	Throttle Opening, Full or Partial		SMOKEBOX By Thermometer	SMOKEBOX By Pyrometer	Firebox by Pyrometer	Testing Plant, Engine Room
	R. P. M. Cut-off Throttle	407	196	198	199	200	201	203	204	206	207	212	208
5006	80-30-F	9-12	2.00	80	14.5	398.2		Full			456	2363	73
5007	80-50-F	9-13	2.00	80	14.5	398.2		"			470	2445	69
5008	120-50-F	9-13	1.00	120	21.7	597.2		"			523	2530	83
5009	120-60-F	9-14	1.00	120	21.7	597.2		"			556	2610	78
5010	160-65-F	9-14	1.00	160	28.9	796.3		"			609	2820	79

TEST NUMBER	BOILER PERFORMANCE — PRESSURE POUNDS PER SQ. IN.				QUALITY OF STEAM IN DOME PER CENT.	DRAFT, INCHES OF WATER				FUEL FIRED	
	Air in Testing Plant, Barometric	IN BOILER Average	IN BOILER Maximum	IN BOILER Minimum		IN SMOKEBOX Front of Diaphragm	IN SMOKEBOX Back of Diaphragm	In Firebox	In Ashpan	Kind of Fuel	Total Pounds, For Test
	221	217	218	219	228	222	223	224	225	232	233
5006	14.20	204.6	205	204		2.2	1.5	0.5	0.17	Bituminous	4427
5007	14.18	205.2	206	204		4.9	3.4	1.9	0.28	Coal,	6889
5006	14.13	205.3	206	203		7.5	5.2	2.3	0.58	Screened	4377
5009	14.12	204.6	205	204		10.9	7.4	2.9	0.67	"	6094
5010	14.07	204.3	206	201		16.6	11.0	3.4	1.00	"	9480

TEST NUMBER	BOILER PERFORMANCE — ANALYSIS OF FUEL (PROXIMATE) PERCENTAGE OF					CALORIFIC VALUE B.T.U. PER POUND		FUEL AND ASH TOTAL POUNDS			DRY FUEL FIRED PER HOUR POUNDS
	Fixed Carbon	Volatile Combustible	Moisture	Ash	Sulphur, Determined Separately	Of Dry Fuel	Of Combustible	Dry Fuel Fired	Combustible by Analysis	Ash by Analysis	
	241	242	243	244	245	248	249	235	236	237	338
5006	54.00	31.00	0.92	14.08	1.14	13088	15258	4358	3763	623	2179
5007	"	"	"	"	"	"	"	6781	5856	970	3391
5008	"	"	"	"	"	"	"	4309	3720	616	4309
5009	"	"	"	"	"	"	"	5999	5180	858	5999
5010	"	"	"	"	"	"	"	9332	8058	1335	9332

Table II.
TEST CONDITIONS AND BOILER PERFORMANCE.
Tests with arch.

M. P. 394 A– Third Sheet
8 x 10½

7 6 1907

Pennsylvania Railroad Company

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-2
CLASS L1s
NUMBER 1165

Bulletin No.30

Average Results of Locomotive Tests

SUBJECT: Brick Arch Tests.

ALTOONA, PA., 9-26-1916.

BOILER PERFORMANCE

TEST NUMBER	TEST DESIGNATION	DRY FUEL FIRED PER HOUR PER SQ. FT. OF GRATE, LBS.		CINDERS AND SPARKS: POUNDS PER HOUR: Cinders Collected in Smoke Box	Sparks Discharged from Stack	Total Cinders and Sparks	CALORIFIC VALUE B. T. U. PER POUND: Of Cinders	Of Sparks	ANALYSIS OF SMOKE BOX GASES: Oxygen O	Carbon Monoxide CO
	R. P. M. Cut-off Throttle	339		238	239	240	250	251	253	254
5006	80-30-F	31.0							6.2	0.0
5007	80-50-F	48.3							4.4	0.0
5008	120-50-F	61.3							3.9	0.0
5009	120-60-F	85.4							5.2	0.1
5010	160-65-F	132.8							0.9	0.1

BOILER PERFORMANCE

TEST NUMBER	ANALYSIS OF SMOKE BOX GASES: Carbon Dioxide CO_2	Nitrogen N	BOILER FEED WATER: Delivered to Injectors, Pounds	LOST: From Boiler Pounds	From Injector Pounds	Delivered to Boiler and Presumably Evaporated Pounds	Temperature of Feedwater Degrees F		EVAPORATION: Steam Delivered by Boiler Pounds per Hour	DRY STEAM, POUNDS PER HOUR: Delivered by Boiler	Per Square Feet of Fire Heating Surface	Per Pound of Dry Fuel
	255	256	259	260	261	264	211		340	341	342	343
5006	12.1	81.8	38986			38986	67.4		19493	19493	4.0	9.0
5007	13.7	81.9	59322			59322	68.6		29661	29661	6.0	8.8
5008	13.3	82.8	35138			35138	69.3		35138	35138	7.2	8.2
5009	12.9	81.8	46370			46370	69.5		46370	46370	9.4	7.7
5010	15.9	83.1	58227			58227	69.0		58227	58227	11.9	6.2

BOILER PERFORMANCE

TEST NUMBER	FACTOR OF EVAPOR-ATION	EQUIV'T EVAP'N FROM AND AT 212° F. LBS.: Per Hour	Per Hour per Square Foot of Fire Heating Surface	PER POUND OF: Fuel, as Fired	Dry Fuel	Combustible		BOILER HORSE POWER (34½ U. of E.)	EFFICIENCY OF BOILER (BASED ON DRY FUEL)	FUEL LOSS DUE TO STEAM LOSS POUNDS PER HOUR	STEAM LOST FROM BOILER POUNDS PER HOUR
	300	344	345	346	347	348		349	350	215	216
5006	1.2784	24922	5.1	11.3	11.4	13.2		722.4	84.8	222	1980
5007	1.2931	38360	7.8	11.1	11.3	13.1		1111.8	83.9	206	1800
5008	1.3008	45715	9.3	10.4	10.6	12.3		1325.1	78.7	20	162
5009	1.3148	60981	12.4	10.0	10.2	11.8		1767.3	75.4	13	102
5010	1.3191	76820	15.6	8.1	8.2	9.5		2226.3	61.0	10	64

Table III.
BOILER PERFORMANCE.
Tests with arch.

M. P. 394 A—Second Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY

Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company

TEST DEPARTMENT

AVERAGE RESULTS OF LOCOMOTIVE TESTS

Bulletin No.30

LOCOMOTIVE:
TYPE 2-8-2
CLASS L1s
NUMBER 1165

SUBJECT: Brick Arch Tests, Arch Removed. ALTOONA, PA., 9-26-1916.

TEST NUMBER	RUNNING CONDITIONS									BOILER PERFORMANCE — TEMPERATURE, DEGREES F.			
	TEST DESIGNATION	Date of Test	Duration of Test Hours	Revolutions per Minute	Speed in Miles per Hour	Piston Speed in Feet per Minute	Reverse Lever, Notches from Front	Throttle Opening, Full or Partial		Smokebox By Thermometer	Smokebox By Pyrometer	Firebox by Pyrometer	Testing Plant, Engine Room
	R. P. M. Cut-off Throttle	407	196	198	199	200	201	203	204	206	207	212	208
5017	80-30-F	9-23	2.00	80	14.4	398.2		Full			426	2050	67
5012	80-50-F	9-15	2.00	80	14.5	398.2		"			462	2390	71
5013	120-50-F	9-16	1.00	120	21.7	597.2		"			502	2490	60
5014	120-60-F	9-18	1.00	120	21.7	597.2		"			525	2500	66
5016	160-60-F	9-18	0.75	160	28.9	796.3		"			529	2610	65
5015	160-65-F	9-18	0.50	160	28;9	796.3		"			528	2320	66

TEST NUMBER	BOILER PERFORMANCE — PRESSURE POUNDS PER SQ. IN.				QUALITY OF STEAM IN DOME PER CENT.	DRAFT, INCHES OF WATER				FUEL FIRED	
	Air in Testing Plant, Barometric	In Boiler Average	In Boiler Maximum	In Boiler Minimum		In Smokebox Front of Diaphragm	In Smokebox Back of Diaphragm	In Firebox	In Ashpan	Kind of Fuel	Total Pounds, For Test
	221	217	218	219	228	222	223	224	225	232	233
5017	14.06	205.2	206	204		2.1	1.5	0.6	0.15	Bituminous	4680
5012	14.06	205.0	206	203		4.9	3.3	1.1	0.48	Coal,	7634
5013	14.18	205.4	206	204		7.2	4.8	1.4	0.59	Screened	5000
5014	14.16	204.4	206	201		10.5	6.7	2.0	0.76		7289
5016	14.15	202.5	205	193		12.3	7.8	2.6	0.93		6570
5015	14.15	185.0	202	178		13.9	5.1	3.2	0.76		6612

TEST NUMBER	BOILER PERFORMANCE — ANALYSIS OF FUEL (PROXIMATE) PERCENTAGE OF					CALORIFIC VALUE B. T. U. PER POUND		FUEL AND ASH TOTAL POUNDS			DRY FUEL FIRED PER HOUR POUNDS	
	Fixed Carbon	Volatile Combustible	Moisture	Ash	Sulphur, Determined Separately	Of Dry Fuel	Of Combustible	Dry Fuel Fired	Combustible by Analysis	Ash by Analysis		
	241	242	243	244	245	248	249	235	236	237	338	
5017	54.00	31.00	0.92	14.08	1.14	13088	15258	4607	3978	659	2304	
5012	"	"	"	"	"	"	"	7515	6489	1075	3758	
5013	"	"	"	"	"	"	"	4922	4250	704	4922	
5014	"	"	"	"	"	"	"	7175	6195	1026	7175	
5016	"	"	"	"	"	"	"	6468	5585	925	8624	
5015	"	"	"	"	"	"	"	6509	5620	931	13018	

Table IV.
TEST CONDITIONS AND BOILER PERFORMANCE.
Tests without arch.

M. P. 394 A—Third Sheet
8 x 10½

7 6 1907

PENNSYLVANIA RAILROAD COMPANY
Philadelphia, Baltimore & Washington Railroad Company
Northern Central Railway Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-2
CLASS L1s
NUMBER 1165

Bulletin No.30

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Brick Arch Tests, Arch Removed. ALTOONA, PA., 9-26-1916.

BOILER PERFORMANCE

TEST NUMBER	TEST DESIGNATION	DRY FUEL FIRED PER HOUR PER SQ. FT. OF GRATE, LBS.		CINDERS AND SPARKS: POUNDS PER HOUR: Cinders Collected in Smoke Box	Sparks Discharged from Stack	Total Cinders and Sparks	CALORIFIC VALUE B. T. U. PER POUND: Of Cinders	Of Sparks	ANALYSIS OF SMOKE BOX GASES: Oxygen O	Carbon Monoxide CO
	R. P. M. Cut-off Throttle	339		238	239	240	250	251	253	254
5017	80-30-F	32.8							6.1	0.2
5012	80-50-F	53.5							4.8	0.1
5013	120-50-F	70.0							5.2	0.1
5014	120-60-F	102.0							3.1	0.1
5016	160-60-F	122.7							3.6	0.3
5015	160-65-F	185.3							3.0	0.9

BOILER PERFORMANCE

TEST NUMBER	ANALYSIS OF SMOKE BOX GASES: Carbon Dioxide CO_2	Nitrogen N	BOILER FEED WATER: Delivered to Injectors, Pounds	LOST: From Boiler Pounds	From Injector Pounds	Delivered to Boiler and Presumably Evaporated Pounds	Temperature of Feedwater Degrees F		EVAPORATION: Steam Delivered by Boiler Pounds per Hour	DRY STEAM, POUNDS PER HOUR: Delivered by Boiler	Per Square Foot of Fire Heating Surface	Per Pound of Dry Fuel
	255	256	259	260	261	264	211		340	341	342	343
5017	12.2	81.4	37981			37981	66.1		18991	18991	3.9	8.2
5012	13.2	81.9	60300			60300	69.3		30150	30150	6.1	8.0
5013	12.9	81.8	36676			36676	68.0		36676	36676	7.5	7.5
5014	14.2	82.5	47570			47570	67.0		47570	47570	9.7	6.6
5016	13.8	82.3	37796			37796	66.2		50395	50395	10.3	5.8
5015	13.9	82.2	26949			26949	67.0		53898	53898	11.0	4.1

BOILER PERFORMANCE

TEST NUMBER	FACTOR OF EVAPORATION	EQUIV'T EVAP'N FROM AND AT 212° F. LBS.: Per Hour	Per Hour per Square Foot of Fire Heating Surface	PER POUND OF: Fuel as Fired	Dry Fuel	Combustible		BOILER HORSE POWER (34½ U. of E.)	EFFICIENCY OF BOILER (BASED ON DRY FUEL)	FUEL LOSS DUE TO STEAM LOSS POUNDS PER HOUR	STEAM LOST FROM BOILER POUNDS PER HOUR
	300	344	345	346	347	348		349	350	215	216
5017	1.2919	24535	5.0	10.5	10.7	12.3		711.2	79.0	250	2060
5012	1.2967	39102	8.0	10.3	10.4	12.1		1133.4	77.1	348	2790
5013	1.3013	47728	9.7	9.6	9.7	11.2		1383.7	71.9	290	2160
5014	1.3187	62733	12.8	8.6	8.7	10.1		1818.4	64.8	297	1972
5016	1.3254	66795	13.6	7.6	7.8	9.0		1936.0	57.5	119	694
5015	1.3201	71142	14.5	5.4	5.5	6.3		2062.1	40.6	0	0

Table V.
BOILER PERFORMANCE.
Tests without arch.

M. P. 394 A—Sixth Sheet 8-21-15 8 x 10½

PENNSYLVANIA RAILROAD COMPANY

Bulletin No.30

Philadelphia, Baltimore & Washington Railroad Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-2
CLASS L1s
NUMBER 1165

FUEL: Jamison Coal Over 1-1/4 In.Screen

AVERAGE RESULTS OF LOCOMOTIVE TESTS

SUBJECT: Brick Arch Tests.

ALTOONA, PA., 9-26-1916.

TEST NUMBER	RUNNING CONDITIONS: TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		BOILER PERFORMANCE: Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
5006	80-30-F	2.00	14.5	Full	30.0		204.6	2.2	0.17	13088	
5007	80-50-F	2.00	14.5	"	47.0		205.2	4.9	0.28	"	
5008	120-50-F	1.00	21.7	"	47.2		205.3	7.5	0.58	"	
5009	120-60-F	1.00	21.7	"	58.3		204.6	10.9	0.67	"	
5010	160-65-F	1.00	28.9	"	63.5		204.3	16.6	1.00	"	

TEST NUMBER	BOILER PERFORMANCE: Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Equivalent Evaporation from and at 212° F., Pounds: Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Average Smoke, Percent	ENGINE PERFORMANCE: Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
5006	2179	31.0	19493	24922	5.1	11.4	722.4	84.8	2	200.8	132.5
5007	3391	48.3	29661	38360	7.8	11.3	1111.8	83.9	4	197.8	165.2
5008	4309	61.3	35138	45715	9.3	10.6	1325.1	78.7	4	194.3	183.5
5009	5999	85.4	46370	60981	12.4	10.2	1767.3	75.4	8	189.4	209.3
5010	9332	132.8	58227	76820	15.6	8.2	2226.3	61.0	22	180.1	221.2

TEST NUMBER	ENGINE PERFORMANCE: Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		LOCOMOTIVE PERFORMANCE: Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
5006	17513	925.5	2.11	18.93		21602	833.7	2.4	21.0	90.0	8.3	
5007	27861	1486.1	2.14	18.74		35907	1385.7	2.3	20.2	93.2	8.5	
5008	34976	1918.3	2.25	18.23		31004	1795.2	2.4	19.5	93.6	8.1	
5009	46260	2364.4	2.53	19.56		39362	2279.0	2.6	20.3	96.4	7.4	
5010	58163	2790.3	3.34	20.84		34284	2646.4	3.5	22.0	94.8	5.5	

Table VI.
SUMMARY OF TEST RESULTS WITH ARCH.

M. P. 394 A—Sixth Sheet

8-21-15
8 x 10½

PENNSYLVANIA RAILROAD COMPANY Bulletin No.30

Philadelphia, Baltimore & Washington Railroad Company
West Jersey & Seashore Railroad Company
TEST DEPARTMENT

LOCOMOTIVE:
TYPE 2-8-2
CLASS L1s
NUMBER 1165

FUEL: Jamison Coal

AVERAGE RESULTS OF LOCOMOTIVE TESTS Over 1-1/4 In. Screen

SUBJECT: Brick Arch Tests, Arch Removed

ALTOONA, PA., 9-26-1916.

TEST NUMBER	RUNNING CONDITIONS						BOILER PERFORMANCE				
	TEST DESIGNATION	Duration of Test, Hours	Miles per Hour	Throttle Opening, Full or Partial	Actual Cut-off Per Cent., H. P. Cylinders		Pressure in Boiler, Lbs. per Sq. Inch	Draft in Smoke Box, Inches of Water	Draft in Ash Pan, Inches of Water	Calorific Value of Dry Fuel, B. T. U. per Lb.	Cinders Collected in Smoke Box, Pounds per Hour
	R. P. M. Cut-off Throttle	196	199	203	268 to 271		217	222	225	248	238
5017	80-30-F	2.00	14.4	Full	29.6		205.2	2.1	0.15	13088	
5012	80-50-F	2.00	14.5	"	47.9		205.0	4.9	0.48	"	
5013	120-50-F	1.00	21.7	"	47.3		205.4	7.2	0.59	"	
5014	120-60-F	1.00	21.7	"	57.6		204.4	10.5	0.76	"	
5016	160-60-F	0.75	28.9	"	60.1		202.5	12.3	0.93	"	
5015	160-65-F	0.50	28.9	"	64.2		185.0	13.9	0.76	"	

TEST NUMBER	BOILER PERFORMANCE									ENGINE PERFORMANCE	
				EQUIVALENT EVAPORATION FROM AND AT 212° F., POUNDS							
	Dry Fuel Fired per Hour, Pounds	Dry Fuel per Hour, Pounds per Sq. Ft. of Grate	Water Delivered to Boiler, Pounds per Hour	Per Hour	Per Hour per Sq. Ft. of Fire Heating Sur.	Per Pound of Dry Fuel	Boiler Horse Power (34½ U. of E.)	Efficiency of Boiler, Based on Fuel	Average Smoke Percent	Pressure in Branch Pipe, Pounds per Sq. In.	Superheat in Branch Pipe Degrees F.
	338	339	340	344	345	347	349	350		220	230
5017	2304	32.8	18991	24535	5.0	10.7	711.2	79.0	14	200.8	155.5
5012	3758	53.5	30150	39102	8.0	10.4	1133.4	77.1	10	197.1	172.7
5013	4922	70.0	36676	47728	9.7	9.7	1383.7	71.9	10	195.0	178.6
5014	7175	102.1	47570	62733	12.8	8.7	1818.4	64.8	16	186.1	212.0
5016	8624	122.7	50395	66795	13.6	7.8	1936.0	57.5	40	181.7	227.2
5015	13018	185.3	53898	71142	14.5	5.5	2062.1	40.6	76	160.3	226.9

TEST NUMBER	ENGINE PERFORMANCE					LOCOMOTIVE PERFORMANCE						
	Dry Steam to Engines, Pounds per Hour	Indicated Horse Power	Dry Fuel per Indicated Horse Power Hour, Pounds	Dry Steam per Indicated Horse Power Hour, Pounds		Drawbar Pull, Pounds	Dynamometer or Drawbar Horse Power	Dry Fuel per Dynamom. Horse Power Hour, Pounds	Dry Steam per Dynamom. Horse Power Hour, Pounds	Machine Efficiency of Locomotive, Per Cent.	Thermal Efficiency of Locomotive, per Cent., (Based on Fuel)	
	214	379	380	381		265	383	384	385	398	399	
5017	16931	937.6	2.19	18.06		20936	803.0	2.6	21.1	85.6	7.6	
5012	27360	1491.1	2.29	18.35		36120	1393.9	2.5	19.6	93.5	7.9	
5013	34516	1866.4	2.48	18.50		30193	1748.0	2.7	19.8	93.7	7.3	
5014	45598	2333.0	2.95	19.55		37586	2175.8	3.2	21.0	93.4	6.2	
5016	49701	2602.8	3.27	19.10		32218	2486.6	3.4	20.0	95.5	5.7	
5015	53898	2551.1	5.10	21.13		31070	2398.0	5.4	22.5	94.0	3.6	

Table VII.
SUMMARY OF TEST RESULTS WITHOUT ARCH.

PENNSYLVANIA RAILROAD COMPANY

PHILADELPHIA, BALTIMORE & WASHINGTON RAILROAD COMPANY
WEST JERSEY & SEASHORE RAILROAD COMPANY

TEST DEPARTMENT

BULLETIN No. 26

TRAIN RESISTANCE

AND

TONNAGE RATING

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ALTOONA, PENNA.

1915

TRAIN RESISTANCE AND TONNAGE RATING.

THE GENERAL METHODS OF OBTAINING TRAIN RESISTANCE AND THE DEVELOPMENT OF RATINGS FOR LOCOMOTIVES AS PRACTICED BY THE PENNSYLVANIA RAILROAD.

INTRODUCTION.

1. The subject of train resistance has been studied by various authorities. It is not our purpose, however, to take up in this Bulletin a general discussion of those studies, but to present the principal results obtained in tests on the various divisions of the Pennsylvania Railroad and to show how the present practice of train loading has been developed.

2. The data presented, therefore, has been taken under the service conditions of the Pennsylvania Railroad and might be materially changed if taken under the possibly different conditions found on other railroads. That there are such differences in conditions is clearly shown in a review of 61 different formulæ for train resistance and the conditions under which they were established, as given in Bulletin No. 84 of the American Railway Engineering and Maintenance of Way Association, February, 1907.

3. In the determination of the resistance of our trains, a dynamometer car is used as a means of measuring the drawbar pull and speed. The car has proved very useful in the rating of the hauling capacity of locomotives and is of great importance as a means of increasing the efficiency of operation by the proper loading of trains. It measures the force that is required to haul a train and from this measurement of drawbar pull, taken under a wide variety of conditions incident to train operation, much useful data can be obtained.

4. Some of the factors which are of importance in train loading and which can be determined by the use of a dynamometer car, are as follows:

(*a*) The drawbar pull per ton of car and lading for cars of various classes when operated over different track conditions.

(*b*) The drawbar pull variations which are caused by different weather conditions.

(*c*) The starting force of locomotives and such data in regard to their operation as cannot be obtained at the Locomotive Testing Plant.

(*d*) The resistance of trains when passing around curves, from which may be calculated the necessary compensation to be made in the grade to equalize resistance on curves and tangents.

Dynamometer Car.

5. The great usefulness of the dynamometer car has long been appreciated. In the early sixties, a car with a crude weighing apparatus, similar to an ordinary butcher's balance, was in use on the Pennsylvania Railroad. The first car was followed by two others, each of larger capacity than its predecessor but based upon the same principle of measuring drawbar pull by the deflection of a calibrated helical spring.

6. A fourth car, built in 1885, was the first to be provided with an adequate equipment of both weighing and recording apparatus. It has a capacity of 28,000 pounds and its weighing device is based upon the double lever principle, using Emery fulcrum plates instead of knife edges. The capacity of this car, although adequate to meet the demands made upon it at the time it was built, was outgrown after it was placed in service by the rapid increase in the size of locomotives. This car was loaned to the Pennsylvania State College in 1911 and is used for the instruction of students in the Railway Mechanical Engineering course.

7. The fifth car, the one now in use by the Pennsylvania Railroad Company, was placed in service in September, 1906. It has a capacity of 100,000 pounds. Briefly, the operation of this car is as follows: A thrust or pull upon the coupler is transmitted through the drawbar of the car to the piston of a hydraulic cylinder situated within the center sill at a point near the middle of the car. The hydraulic pressure set up in this main cylinder is transmitted, by means of oil with which both cylinders and connecting pipes are filled, to a smaller recording cylinder within the body of the car. Movement of the piston in the recording cylinder is resisted by calibrated helical springs, the deflections of which (and the resulting movement of the piston) are proportional to the pull or push upon the coupler. A pen, actuated by the piston rod of the recording cylinder, marks upon strip of paper, which

moves beneath it, an irregular line, the distance of which from the datum line is proportional to the drawbar pull upon the coupler. This car resembles the standard wooden passenger car except for the fact that it is a trifle shorter; has but one platform and has trucks of a rather unusual design. Illustrations of the car are shown in Figs. 1, 2 and 3. The car has been in almost continuous use since its construction in 1906. The principal work has been tonnage rating on the various divisions of the Lines East and West of Pittsburgh.

Relation of Resistance to Speed.

8. The factors which make up the resistance to the movement of a car on level tangent track may be placed under three principal divisions:

(*a*) Journal resistance, or that due to the rubbing of the journal and bearing.

(*b*) Air resistance, including wind resistance.

(*c*) Miscellaneous, or those resistances which are due to concussion, flange friction and the rolling of the wheels upon the rail.

9. Of the three divisions of resistance the third depends so largely upon the condition of the roadbed and cars and the make-up of the train, that its relation to the speed cannot be definitely established. Although its value may change with the speed of the train, assuming that the cars and roadbed are in first class condition, practical means are not available for separating the so called miscellaneous resistance from the journal and air resistance and, therefore, it may be considered a constant quantity at speeds up to twenty-five miles per hour, and the assumption made that the journal and air resistances change with the speed of the train.

10. The journal resistance or the resistance offered by dry surfaces rubbing together does increase with the speed of the train, but with a lubricated journal an increase in speed tends to heat the oil lubricant and lower its viscosity, and this in turn tends to lower the coefficient of friction between the journal and the bearing and the resulting journal resistance.

11. The decrease in journal resistance, however, may be offset, more or less, by the increase in air resistance until a speed is reached at which the viscosity of the oil is a minimum and from this point onward the combined influence of journal and air

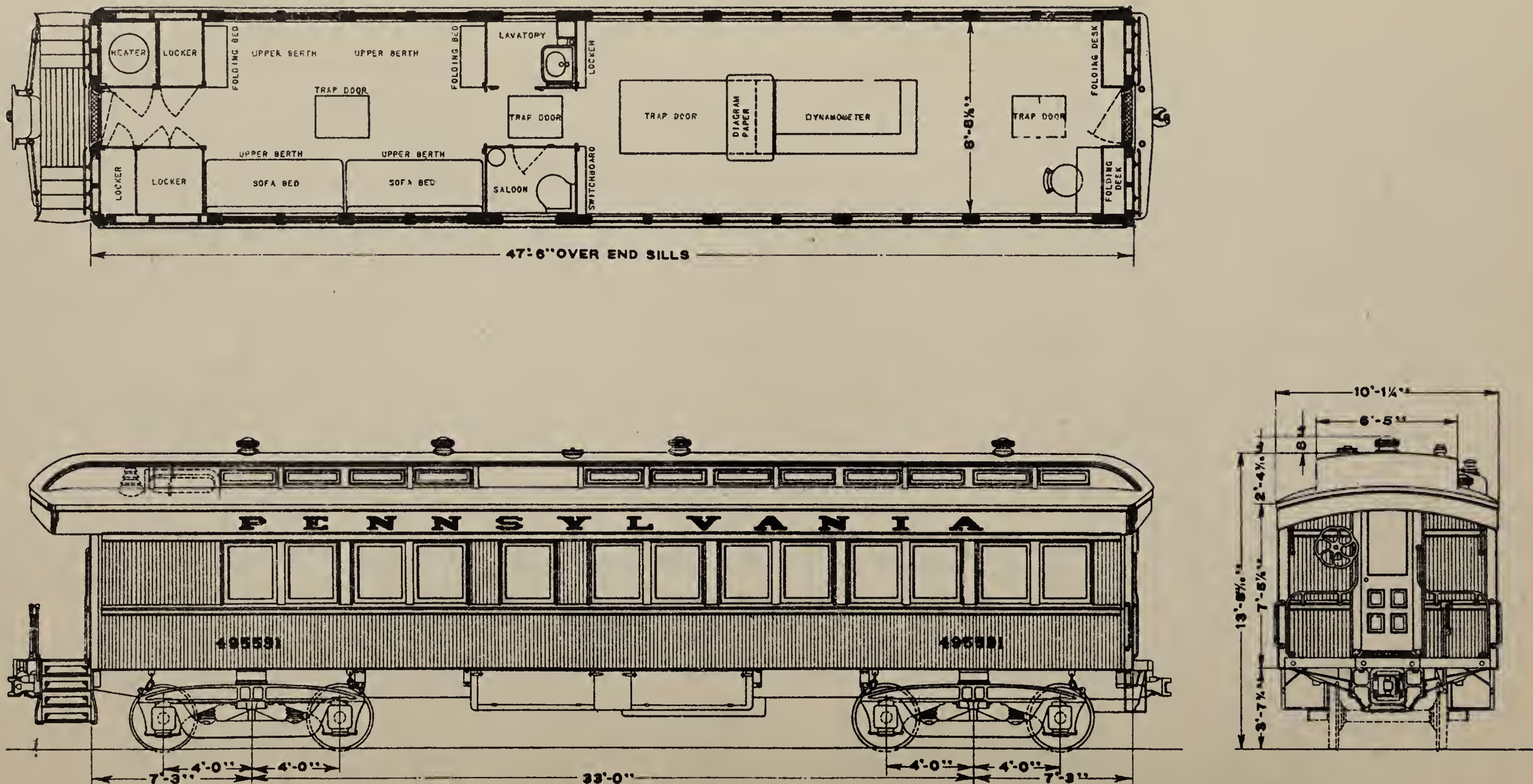

Fig. 1.

DYNAMOMETER CAR No. 495591.

This car, the fifth of the series, was placed in service in September, 1906. Connection to the recording mechanism in the car is made from the coupler at the end without platform. The car weighs 61.6 tons.

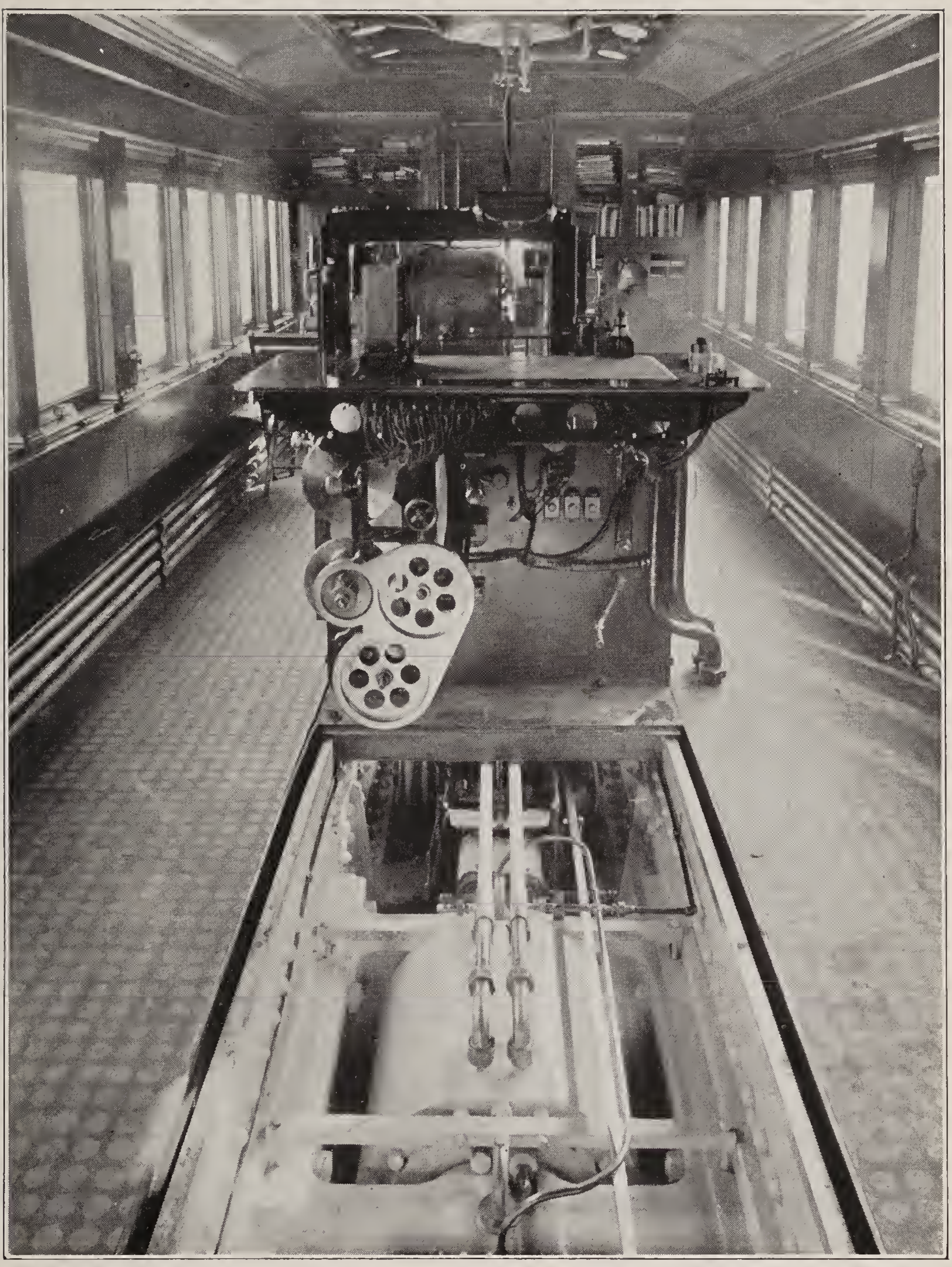

Fig. 2.

DYNAMOMETER CAR.

Main compartment of car showing recording mechanism.

The opening in the floor shows a portion of the main hydraulic cylinder and the two connecting pipes.

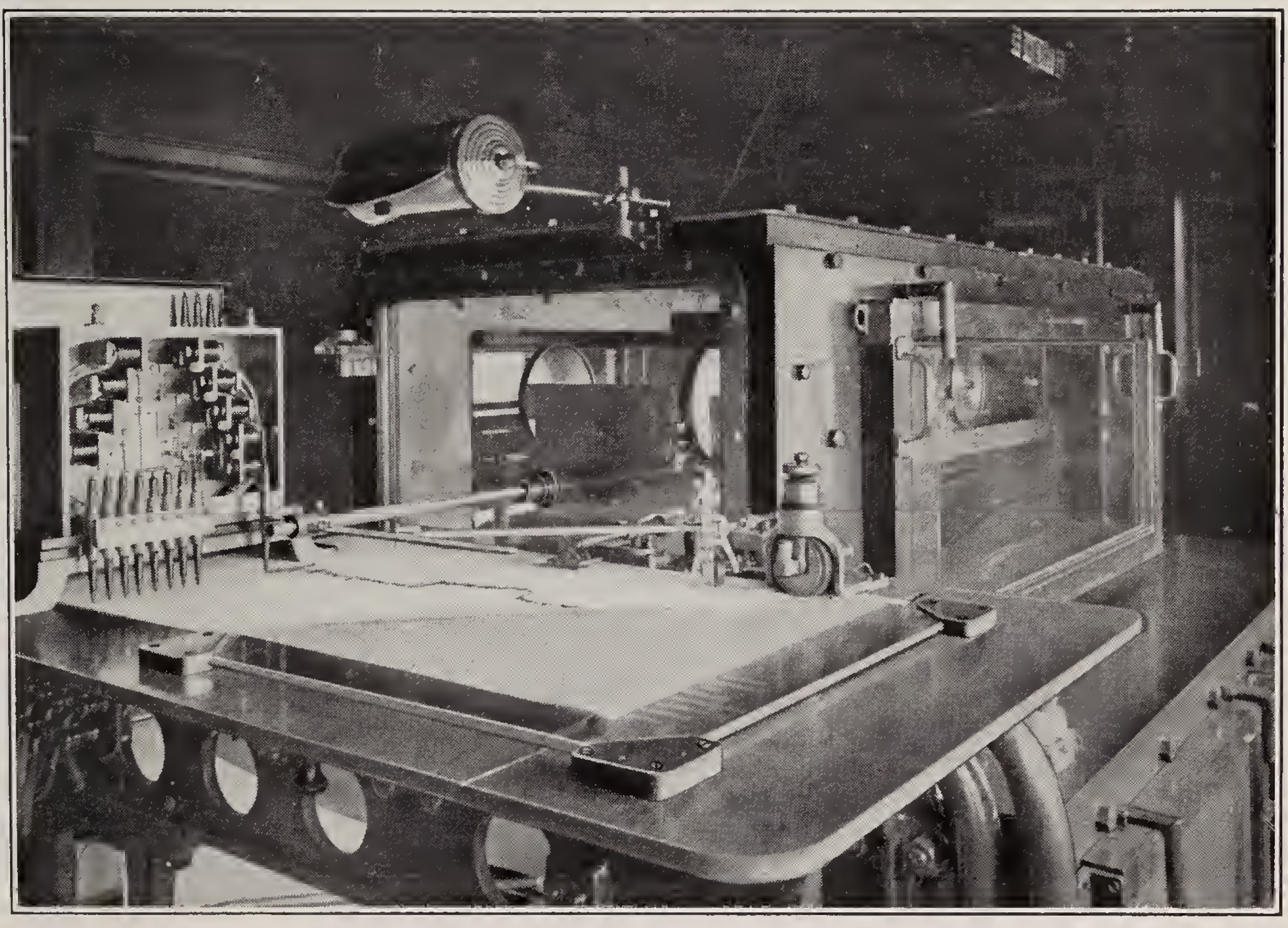

Fig. 3.

DYNAMOMETER CAR RECORDING TABLE.

Provision is made for drawing eight lines in addition to the drawbar pull line. The pens and their controlling magnets are shown on the extreme left. The first line indicates whether the load on the machine is a push or pull; the second records the area of the diagram in square inches between the zero and the pull line; the third indicates the distance passed in five-second intervals of time; the fourth indicates every thousand feet traveled by the car; the fifth and sixth pens, operated by observers on the locomotive, record the time of taking indicator cards, and the steam pressure and position of the throttle and reverse lever. The seventh pen is operated by an observer at a lookout window and is used to denote locations of mile posts, stations, etc. The eighth pen is reserved for extra information as the occasion may demand.

friction tend toward an increase in resistance with the speed. It has been found that at a speed between 20 and 30 miles per hour their combined influences tend to rapidly increase.

12. The fact that the heating of the journals depends upon the time the train has been in motion and its running speed, makes it difficult to prove that the resistance, measured at any given speed, corresponds normally to that speed, for the true resistance at any speed can only be found after that speed has been maintained for some time.

13. It has been observed many times, during dynamometer trials, that the total resistance at speeds up to 25 miles per hour is often as low as at minimum speeds and, therefore, until methods are devised to accurately determine the relation of speed to resistance, the curve shown in Fig. 4 may be taken as showing the average resistance of our freight cars when operated on properly maintained level tangent track at speeds below 25 miles per hour.

The resistance figures from which the curve has been derived were obtained in various dynamometer car tests.

LEVEL TANGENT, GRADE AND CURVE RESISTANCE OF FREIGHT CARS.

14. In 1907 a few tests were made to determine the resistance of a twenty-ton car. It was found that the cars used in these trials showed a level tangent resistance of 8 pounds per ton. Since that time, however, a large number of observations made in tonnage rating work have shown that 7 pounds per ton more nearly represents the average resistance for cars of this weight.

15. In the spring of 1907 an extended investigation was made on the Philadelphia Division, Low Grade Freight Line, to determine the resistance of 100,000 pounds capacity loaded freight cars at the usual operating speeds for heavy freight trains. The average gross weight per car was approximately 72 tons.

16. The tests were made over the 25-mile portion of the line, lying between Columbia and Q Tower. The section of track for which the resistance was computed lies on a 0.3 per cent. ascending grade. Over this section there are several long portions of tangent track and compensated curves of from 15 minutes to 2 degrees in curvature.

17. Fifteen trains, made up of 37 to 56 loaded steel gondolas, were tested. The trains were made up in Enola Yards, a point 30 miles west of Columbia. The river grade between these points permitted an average running speed of 20 miles per hour to be made and insured the car journals being heated up to an average running temperature when the test section east of Columbia was reached. On most of the tests there was little or no wind and the prevailing air temperature was from 60 to 80 degrees Fahr.

18. The elevation and curvature of each stretch of track was known, and the resistance per ton of train hauled, as measured at the drawbar, was corrected for grade to obtain the level tangent and curve resistance.

Level Tangent Resistance.

19. The table, page 14, summarizes the results of the level track resistance on the seven tangents in the tests. Tangents Nos. 3 and 7 come after the stop at SF and Q Towers, respectively. Stops of from 10 to 30 minutes were made at these towers on all the test runs, and some of the runs clearly show the effect of the stop in an increase of resistance on each of these tangents. Tests Nos. 100 and 110, made at the lowest temperature, show a large increase in resistance due to this cause.

20. From the tests the following conclusions were drawn:

(*a*) The level tangent resistance of freight cars, weighing, inclusive of lading, 72 tons, when run at low speeds ranges between $2\frac{1}{2}$ and 4 pounds per ton.

(*b*) On properly maintained track the average value of 3 pounds per ton for the total level tangent resistance may be assigned for cars weighing 70 tons.

21. The values of resistance per ton for cars of intermediate weights shown in Fig. 4 have been calculated from the equation of the line drawn between the points representing the total car resistances of the 20-ton and 70-ton cars, and these values have been closely checked in tonnage rating work.

22. Dynamometer car tests which have recently been made indicate that for cars weighing considerable in excess of those in usual operation, the car resistance values deviate somewhat from a straight line. It should be noted, however, that there are but a limited number of cars in operation on our lines having a gross

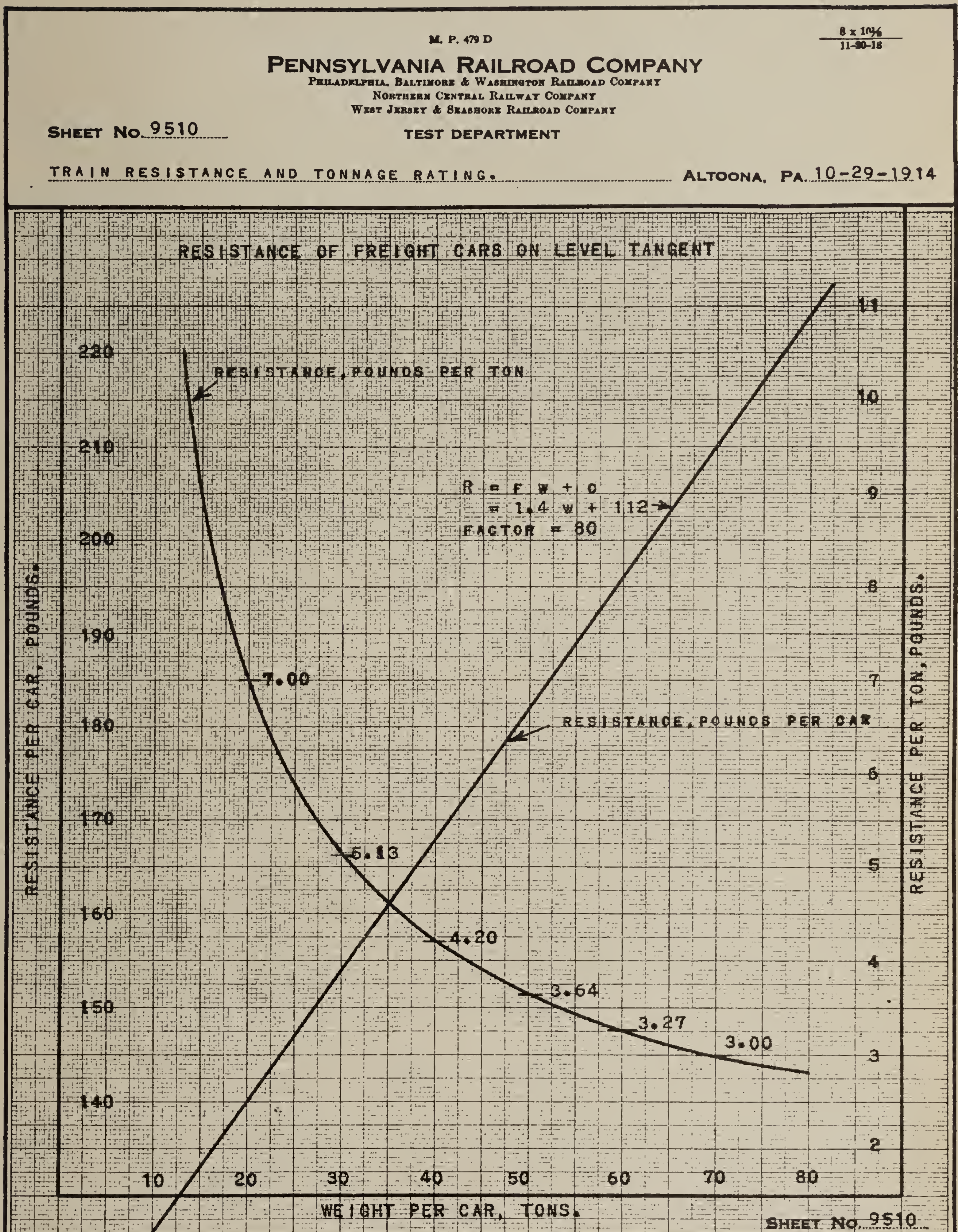

Fig. 4.

LEVEL TANGENT RESISTANCE OF FREIGHT CARS.

This diagram shows the resistance per car and per ton at speeds between 5 and 25 m.p.h. This data was obtained by dynamometer car tests.

weight in excess of 75 tons. These heavy cars are operated in trains made up in part of lighter weight cars, which materially reduces for a given train the average car weight, and therefore, until the heavily loaded cars are in more general use, our present method of freight train loading, which is discussed in the part following Par. 93, and which is based on the assumption that the resistances of cars of various weights can be represented by a straight line, may be used without appreciable error, as it has been proven that this assumption is sufficiently accurate for tonnage rating purposes.

23. Some of the heavier cars which are coming into use are carried on six-wheel trucks, and an investigation of the resistance of these cars has been made. In Fig. 4A are curves showing a relation between car weight and the resistance of six-wheel and four-wheel truck freight cars of large capacity. In this figure the points which are shown are designated as follows:

N. & W. Ry. Class Gka Six-wheel Truck Cars.

A—resistance	per	ton,	empty	cars.
B— "	"	car,	"	"
C— "	"	ton,	loaded	"
D— "	"	car,	"	"

P. R. R. Four-wheel Truck Cars.

E—resistance	per	ton,	class	H21a,	empty	cars.
F— "	"	car,	"	"	"	"
G— "	"	ton,	"	H21,	loaded	"
H— "	"	car,	"	"	"	"
I— "	"	ton,	"	H21a,	"	"
J— "	"	car,	"	"	"	"

Miscellaneous Four-wheel Truck Cars, Phila. Div., 1907.

K—resistance	per	ton,	loaded	cars.
L— "	"	car,	"	"

The curves for the resistance per car and per ton for six-wheel truck cars are based on the average value of 7.27 pounds per ton for the empty class Gka car weighing 30 tons, and 3.17 pounds per ton for the same car loaded to a total weight of 121 tons. The resistance per car for six-wheel truck cars of intermediate weights has been assumed to follow a straight line and the

corresponding resistances per ton have been calculated from it. This latter curve has been extended to show the probable resistance of six-wheel truck cars weighing from 121 tons to 140 tons.

24. The curves of the four-wheel truck cars which have been obtained as explained in Par. 21, have been supplemented by the results obtained in the tests mentioned in paragraphs 40 to 54. In dotted extensions of the curves have been shown the probable resistance curves for four-wheel truck cars weighing from 98 to 140 tons, although such cars have not yet been built for our lines.

25. In prolonging these curves we have assumed that increasing the axle loads from 49,000 pounds (98-ton car) to 70,000 pounds (140-ton car) will not cause a disproportionately greater track deflection and result in an abnormal increase in rolling resistance, and on this assumption the curve indicates that for four-wheel truck cars weighing above 100 tons the resistance per ton will be practically constant.

26. It will be observed that the resistance curve for the six-wheel truck cars and the four-wheel truck cars intersect at a gross weight of car of approximately 140 tons. For cars weighing in excess of 140 tons the indications are that from a resistance standpoint the six-wheel truck car will be preferable to the four-wheel truck car.

27. On the contrary, if abnormal track conditions are introduced by increasing the axle load above 49,000 pounds, then the resistance curve for cars weighing in excess of 98 tons (axle load 49,000 pounds) would tend to rise more rapidly than is shown in the figure. If the dotted extension of the curves for the six-wheel and four-wheel truck cars correctly represent the resistance which will be obtained with cars of heavier weight than those tested, then it appears that from a resistance standpoint, four-wheel truck cars are preferable to six-wheel truck cars when the gross weight of the car is less than 140 tons.

Grade Resistance.

28. The resistance due to an ascending grade is usually a large item in the total train resistance, but as it is dependent only upon the weight of car and the steepness of the grade or the

Table I.

Level Tangent Resistance of 100,000 Pounds Capacity Loaded Freight Cars.

Eastern Pennsylvania Division. Philadelphia Division. Low Grade Freight Line.

Cars owned by			Berwind-White Coal Mining Company.									Mixed Owners, P. R. R., etc.							
Test Numbers			100	104	110	118	122	136	140	156	Avg.	132	142	146	150	154	160	164	Avg.
Weather			Light Snow	Cldy.	Cldy.	Fair	Fair	Fair	Fair	Fair	....	Fair	Fair	Cldy.	Fair	Fair	Cldy.	Cldy.	....
Average temperature			40	52	47	80	70	70	60	73	....	60	77	59	72	74	69	64	....
Number of cars			37	40	41	43	45	48	53	46	....	51	47	51	47	47	56	50	....
Weight of train, tons			2700	2918	2961	3107	3298	3497	3876	3354	....	3680	3438	3665	3411	3446	4037	3582	....
Length of train, feet			1310	1415	1450	1520	1590	1695	1870	1625	....	1800	1660	1800	1660	1660	1975	1765	....
Location, M. P. to M. P.	Length Feet	Average Grade Per Cent.	Level Tangent Resistance—Pounds per Ton																
(1) 69 + 1111 ft. to 68 — 939	7330	0.299	10.6 3.11	11.4 3.04	11.4 2.97	10.7 2.72	8.6 2.55	12.2 2.61	11.5 2.91	10.7 2.71	.... 2.83	10.2 3.27	11.8 3.00	8.4 3.33	10.2 3.27	11.3 2.84	7.7 3.29	11.0 3.30	.... 3.18
(2) 67 + 311 ft. to 67 — 1191	1502	0.297	10.9 3.13	10.3 3.01	10.8 3.10	10.1 2.75	7.3 2.60	11.3 2.63	10.5 2.89	10.8 2.87	.... 2.88	8.2 3.07	11.4 2.90	7.9 3.68	10.4 3.22	11.5 2.93	5.5 3.13	9.6 3.16	.... 3.15
(3) 66 + 877 ft. to 63 + 2035	14682	0.302	9.4 3.43	8.3 3.05	9.3 3.30	9.2 2.86	6.4 2.43	9.3 2.90	7.0 2.68	8.7 2.70	.... 2.92	4.3 3.15	9.4 3.18	6.9 3.57	8.8 3.20	9.5 2.77	4.3 3.42	7.1 3.18	.... 3.21
(4) 62 + 3697 ft. to 62 + 2679	1018	0.292	9.7 3.26	8.6 2.90	10.5 3.05	10.0 3.05	7.3 2.71	11.3 2.85	7.8 2.85	9.2 2.86	.... 2.93	6.1 3.40	9.5 3.15	7.7 3.64	8.8 3.41	9.8 2.91	5.8 3.76	7.4 3.74	.... 3.43
(5) 60 + 3569 ft. to 60 + 1091	2478	0.268	9.3 3.38	8.3 3.16	10.2 3.21	9.8 3.35	7.1 2.78	10.9 3.21	8.1 3.24	9.4 2.83	.... 3.14	7.8 3.51	9.9 3.15	7.4 3.60	8.2 3.77	9.6 2.95	5.4 3.64	8.0 3.90	.... 3.50
(6) 58 + 2689 ft. to 57 — 2461	10430	0.296	10.3 3.12	10.7 3.19	10.6 2.89	11.2 2.99	9.4 2.90	13.3 2.90	9.4 3.03	10.4 2.79	.... 2.97	7.9 3.16	11.7 3.03	9.4 3.84	9.8 3.48	10.9 2.80	5.8 3.67	9.5 3.79	.... 3.40
(7) 55 — 1893 ft. to 53 — 1367	10014	0.306	8.7 3.58	9.2 3.42	8.6 3.67	8.5 3.02	9.2 2.97	7.6 2.59	7.1 2.66	9.1 2.64	.... 3.07	7.1 3.33	8.8 3.30	7.2 3.99	7.4 3.34	9.1 2.73	....	8.5 3.35	.... 3.34
Average	....	....	3.28	3.11	3.17	2.96	2.70	2.82	2.89	2.77	2.96	3.27	3.10	3.66	3.38	2.85	3.48	3.49	3.32

Average for the 15 tests = 3.13 pounds per ton.
Note.—Upper figures are speeds in miles per hour.

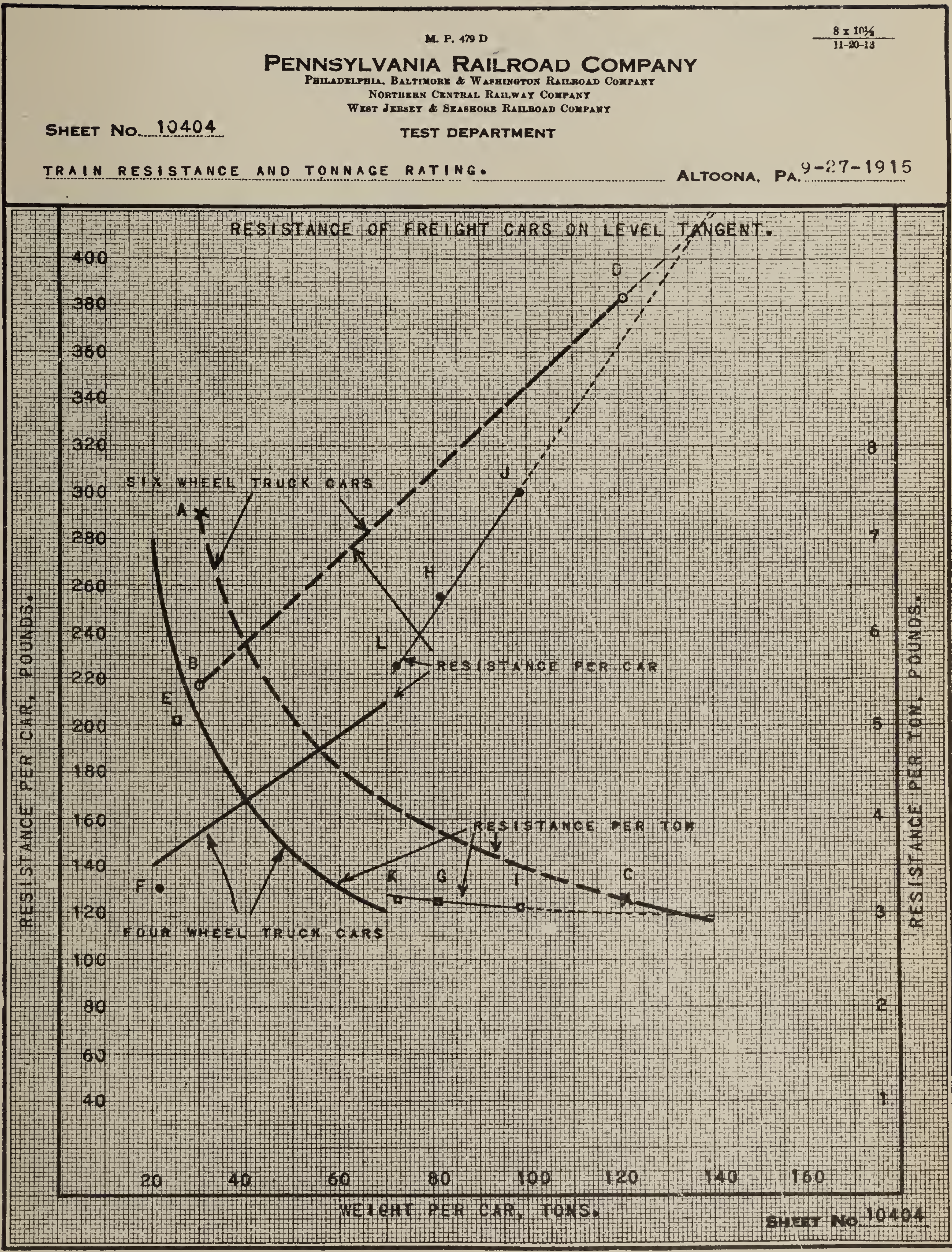

Fig. 4A.

RESISTANCE OF FREIGHT CARS ON LEVEL TANGENT.

The resistance of cars up to 121 tons has been measured and the curves are extended to include the probable resistance of cars weighing 140 tons.

height to which the car is lifted in overcoming the grade, it is capable of exact computation. Without giving the well-known derivation of the formula, we have:

$$r = 20G$$

where r = resistance due to grade alone, in pounds per ton (one ton = 2000 lbs.) G = grade in per cent. To the grade resistance thus computed must be added the resistance which the car is subjected to when moving on level track, in order to obtain the total resistance at speeds below 25 m.p.h. on the tangent track of an ascending grade. For example, the level tangent resistance of a car weighing 70 tons is 3 pounds per ton. The resistance due to grade alone is 20G pounds per ton. On an ascending grade of 0.5 per cent. the total resistance will be 13 pounds per ton.

Curve Resistance.

29. The curve resistance of loaded freight cars was obtained on the Low Grade tests on one 2°–0′, two 1°–0′ and on one 0°–15′ curves. This resistance was computed for two cases, as follows:

(*a*) Train on the curve only.

(*b*) Train passing completely over the curve.

30. In the first case, the average resistance was obtained during the time that the entire train was on the curve and after all the trucks had become adjusted to the curvature. From the resistance thus found, the resistance due to the grade upon the curve was deducted, the final result being the average resistance for the level curve in question. The degree of curvature being known, the average resistance per degree of level curvature was obtained.

31. To obtain the resistance per degree of curvature for a train passing completely over the curve the process is more involved and is based upon the assumption that the work done in overcoming resistances on entering the curve is equal to the work done on leaving it. In this case the resistance is measured from the point where the locomotive enters the curve to the point where the train has been run entirely over the curve and fully on to the next tangent.

32. If the curve is longer than the train, the resistance will increase uniformly from the time the head end of the train enters the curve until the whole train is on the curve, and will thus continue constant until the head end of the train leaves the curve and then decrease uniformly until the rear end of the train clears the curve.

33. If the curve is shorter than the train, the resistance will increase uniformly from the time the head end of the train enters the curve until the head end of the train clears the curve, then remain constant until the rear end of the train enters the curve. Thereafter the resistance will decrease uniformly until the rear end of the train clears the curve.

34. The following table shows the average resistance, in pounds per ton, per degree of level curve obtained in the manner described:

RESISTANCE, POUNDS PER TON PER DEGREE, LEVEL CURVE.

Train Passing Completely over Curve				Train on Curve Only			
Curvature in Degrees	Resistance			Curvature in Degrees	Resistance		
	Maximum	Minimum	Average		Maximum	Minimum	Average
2°–0′	1.54	0.76	1.01	2°–0′	1.16	0.12	0.58
1°–0′	0.98	0.20	0.51	1°–0′	1.22	0.42	0.74
1°–0′	1.68	0.47	0.89	1°–0′	1.74	0.69	1.13
				0°–15′	1.32	0.08	0.87
Average..			0.80	Average..			0.83

35. From this table it will be seen that although the resistance on the 2°–0′ curve is greater when the train passed completely over than when running on the curve only, the contrary is the case on the 1°–0′ curve. It would be expected that the force required to turn the trucks on entering and on leaving the curve would make the results higher for the train passing completely over the curve than for the curve only.

36. From these tests the following conclusions were drawn:

(*a*) For a freight car weighing 72 tons, inclusive of lading, the resistance, per ton, per degree of level curve, may be as low as 0.10 pounds or as high as 1.75 pounds.

(*b*) A fair average for curve resistance at low speeds may be taken as 0.8 pounds per ton per degree of level curve.*

37. The level tangent and curve resistances obtained over the various sections on the Low Grade Line tests are shown in Fig. 5.

Resistance on Humps.

38. In the fall of 1906 some tests were made on the humps at Enola and Hollidaysburg Yards to determine the resistance of empty and loaded freight cars at slow speeds, i. e., one-half to two miles per hour. The number of tests was not sufficient to arrive at definite conclusions, but the indications are that at these speeds the resistance of an empty car (20 tons weight) on level tangent track is 30 pounds per ton, and for a loaded car (70 tons weight) 10 pounds per ton, which resistances are approximately four times the level track resistance as shown in Fig. 4, for speeds from 5 to 25 miles per hour.

39. On the ascending grade of a hump the resistance due to grade must be added to the above figures. Thus on a 1.5 per cent. grade the resistance per ton for the empty cars would be $30+(20\times1.5)=60$ pounds and for the loaded cars $10+(20\times1.5)=40$ pounds.

Resistance Tests of Large Capacity Freight Cars.

40. The resistance of loaded cars having a gross weight of from 80 to 120 tons as referred to in Pars. 23–27 was determined in a series of dynamometer car tests made on the Middle Division between Petersburg and Harrisburg in 1914 and 1915. In these tests a train made up of 50 P. R. R. class H21 gondola cars, loaded with coal to an average gross weight of 81 tons, a train of 50 P. R. R. class H21a gondola cars having an average gross weight of 98 tons, and a train of 50 N. & W. Ry. class Gka gondola cars each having a gross weight of 121 tons, were run eastbound and westbound over the Division, three

* Thus a curve of one degree offers the same resistance as a grade of 0.04 per cent., a curve of two degrees the same as a grade of 0.08 per cent., etc.

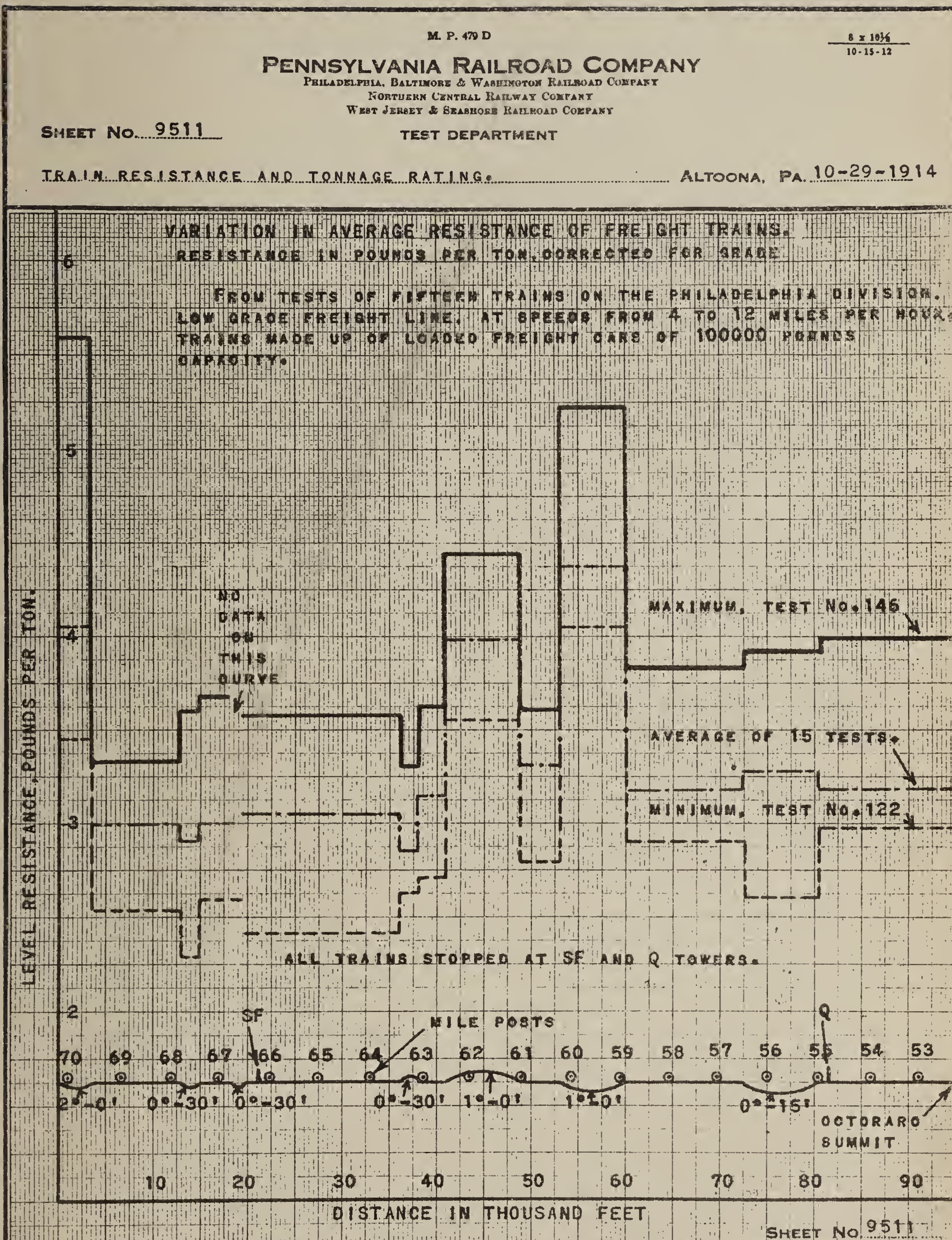

Fig. 5.

LEVEL CURVE AND TANGENT RESISTANCE OF FREIGHT CARS.

These data were obtained from trains of loaded cars of an average weight per car of 72 tons. An increase in level resistance is obtained when the train is on a curve. The level tangent resistance is high on the tangent stretches beyond SF and Q Towers, showing the effect of a stop in increasing the resistance. Note the gradual increase in level tangent resistance as the grade is ascended.

or more trips being made in each direction with each train, and the same cars used throughout the tests on that particular class of car. All of the cars were in good running condition, having been in service for a considerable length of time. The temperature during these tests was above 45° F.

The P. R. R. classes H21 and H21a cars are steel self-clearing quadruple hopper cars and have permissible maximum carrying capacities of 121,000 and 154,000 pounds respectively. They differ only in style of trucks; the H21 cars having four-wheel Diamond trucks with 33-inch steel wheels and $5\frac{1}{2}$ x 10 inch journals, and the H21a cars having four-wheel trucks with cast-steel side frames, 33-inch steel wheels and $6\frac{1}{2}$ x 11 inch journals.

41. The N. & W. Ry. class Gka cars are flat bottom steel gondolas which have a maximum carrying capacity of 198,000 pounds. These cars are equipped with six-wheel trucks which have $5\frac{1}{2}$ x 10 inch journals and 33-inch steel wheels.

42. The resistance of these trains while running over the division, was determined upon 13 stretches of tangent track, each stretch longer than the test train, but the resistance figures were obtained from the dynamometer diagram representing lengths of tracks from 1200 to 2200 feet. These tangent stretches were not located on level track and it was, therefore, necessary to make allowance for the grade condition in order to obtain the resistance on level tangent track.

43. A grade correction can be determined if, over the given stretch of track there is a uniform rise or fall in grade, but over the stretches considered in these tests this condition did not exist and consequently the influence of the grade in increasing or decreasing the resistance of the train could not be computed with exactness.

44. The resistance on level tangent track was obtained by taking the average of the resistance found in one direction and that obtained in the opposite direction over the same stretch of track, so that the increase in resistance due to an ascending grade in one direction was offset by the lower resistance of the train, due to the descending grade in the opposite direction.

45. As far as practicable during each test the speed of the train over the Division was kept at between 10 and 15 miles per hour, in order that the car journals might have a uniform running

temperature. The heating of the journals depends largely upon the time the train has been in motion and its running speed, and allowances were made for the variation in journal temperature by omitting from the averages the tests in which the trains were stopped for five minutes or more in the half hour preceding the entrance of the train to each of the tangent stretches, and also tests in which the average speed prior to entering various sections was considerably under or above the nominal speed of the tests. Even after consideration had been given to these factors, there was a considerable variation in the results of the tests on any one type of car.

Cars Fully Loaded.

46. The maximum, minimum and average resistances in pounds per ton for the various classes of gondola cars when fully loaded and operating on level tangent track at a speed of from 10 to 15 miles per hour, is as follows:

Class of Car	Trucks	Size of Journals, Inches	Average Weight		Resistance, Pounds Per Ton		
			Per Car and Lading Tons	Per Axle Lbs.	Maximum	Minimum	Average
P. R. R. H21..	Four-wheel	$5\frac{1}{2}$ by 10	81.11	40,555	3.55	2.76	3.13
P. R. R. H21a	Four-wheel	6 by 11	98.47	49,235	3.34	2.77	3.05
N. & W. Ry. Gka.	Six-wheel..	$5\frac{1}{2}$ by 10	121.12	40,373	3.36	2.90	3.17

47. An interesting illustration of the variation which may be found in the resistance of freight trains in regular service, is given in Fig. 5A. The data was obtained on the tests of the P. R. R. class H21a cars fully loaded. In this figure have been plotted the average resistance in pounds per ton of train weight for the three trains when operated westbound over the several stretches of tangent track and the resistance over the same stretches of adjacent track when the trains were run eastbound.

48. In general the grades were ascending westbound and the resistances over a given stretch in this direction were, therefore, higher than in the opposite direction.

It will be observed that negative resistances are shown for the trains when run eastbound over Sections 7, 10 and 13.

These negative resistances were due to the comparatively heavy descending eastbound grades which resulted in the train pushing the locomotive. The opposite effect of the grade is shown by the higher resistances obtained when the trains were run westbound.

49. The average of the resistances obtained in the eastbound and westbound tests is shown in heavy lines and represents the resistance on level tangent track, its maximum value in the case shown was 3.34 pounds per ton (Section 7) and the minimum value 2.77 pounds per ton (Section 12). The average resistance over all sections is 3.05 pounds per ton.

Cars with Equal Axle Load.

50. The resistance of the same train of class H21a cars with the load in the cars reduced so as to have the same axle load as was had in tests of the class H21 cars, was obtained during the trials on the Middle Division with the following results:

Class of Car	Size of Journals, Inches	Average Weight		Resistance, Pounds Per Ton		
		Per Car and Lading Tons	Per Axle Lbs.	Maximum	Minimum	Average
P. R. R. H21	$5\frac{1}{2}$ by 10	81.11	40,555	3.55	2.76	3.13
P. R. R. H21a	6 by 11	80.96	40,480	3.37	2.75	3.11

These results indicate that when equally loaded there is little difference between the resistances offered by the two types of truck.

Empty Cars.

51. The resistance of empty cars of the Gka and H21a class was also obtained in the tests on the Middle Division. These results, based on level tangent track, are as follows:

Class of Cars	Light Weight, Tons	Resistance, Pounds Per Ton		
		Maximum	Minimum	Average
N. & W. Ry. Gka	30.15	7.85	6.75	7.27
P. R. R. H21a	25.40	6.01	4.11	5.04

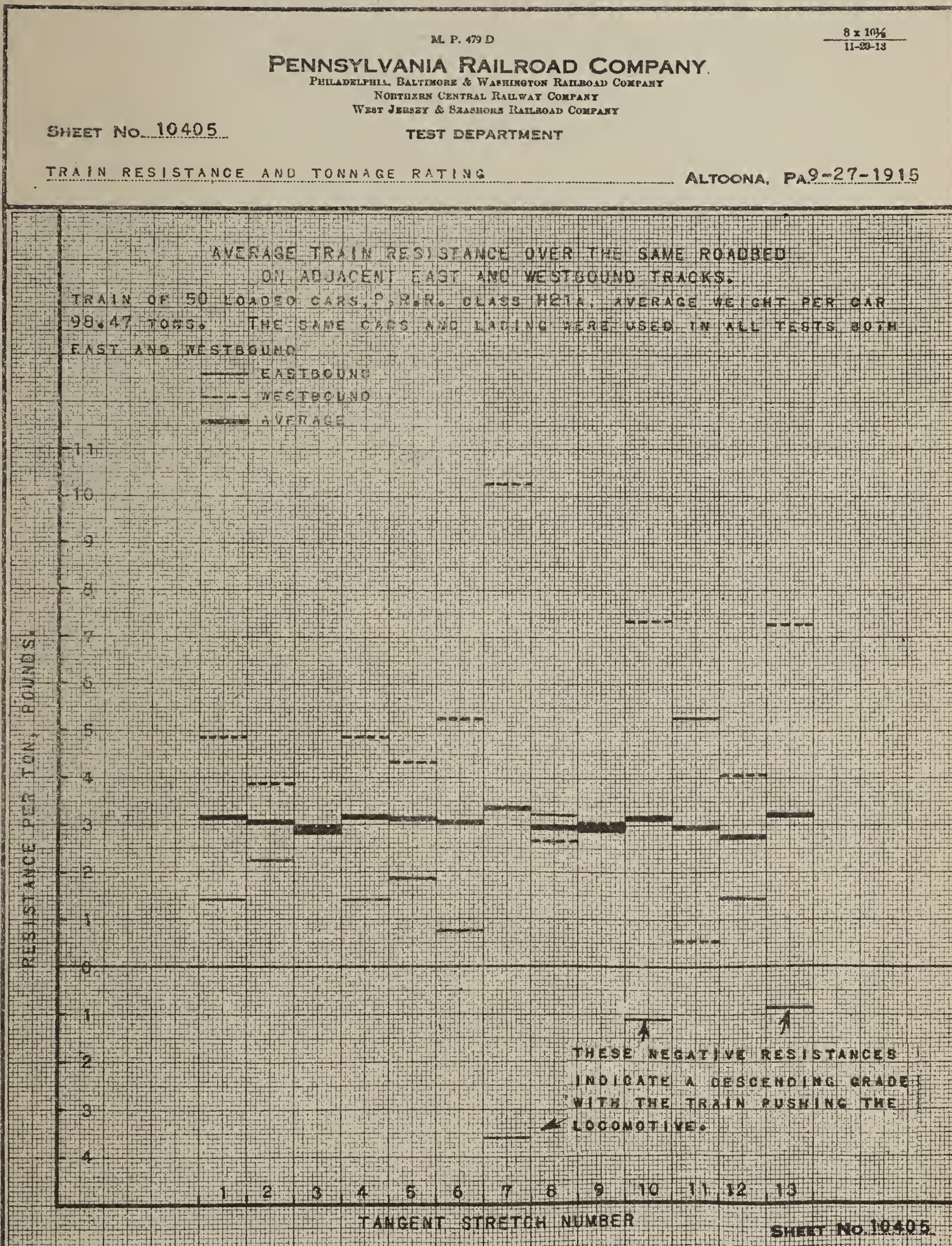

Fig. 5A.

TRAIN RESISTANCE OVER TYPICAL TANGENT STRETCHES.

By measuring the resistance in two directions and averaging, the effect of grade is eliminated. The average level tangent resistance is close to three pounds per ton.

52. The resistance of the class H21a cars (5.04 lbs. per ton) is somewhat lower than that shown in Fig. 4 for a car of 25 tons weight (5.88 lbs. per ton). The class H21a cars were known to be in good running condition and to a certain extent may be the cause of the resistance showing lower than is indicated by the curve in Fig. 4 which curve is based on cars in average service condition.

53. The resistance per ton of the class Gka cars is higher than that shown in Fig. 4 for cars of equal weight and may be due to the greater number of axles per truck.

RESISTANCE OF PASSENGER CARS.

54. Considerable data pertaining to the resistance of passenger cars has been accumulated as a result of dynamometer car tests. This data shows that at the higher speeds at which these cars operate, the combined effect of the journal and atmospheric resistance undergoes a considerable increase as the speed is increased.

55. The journal friction is at its maximum at starting and reaches its minimum value at from 25 to 30 miles per hour. It is then constant or has a very gradual increase as the speed is increased.

56. The effect of atmospheric resistance increasing as a function of the speed is offset at the lower speeds by the decreasing journal friction; the combined effect of wind and journal friction rapidly increases as the speed is increased above 25 or 30 miles per hour.

Passenger Equipment Steel Cars.

57. There have been plotted in Fig. 6 the resistances on level tangent track at speeds from 30 to 75 miles per hour. The points were obtained with regular service passenger trains on the well ballasted track of the New York Division.

58. The trains were made up of five to ten steel cars, and included from one to four Pullman or dining cars, having six-wheel trucks. The remaining cars were either P–70 or combined cars having four-wheel trucks. The average weight of the cars was 65 tons, which weight included passengers and baggage.

59. From the resistance figures obtained on the various trains no consistently greater increase in resistance was found for those trains having the greater number of six-wheel truck cars. In fact some 10 car trains made up of six four-wheel truck cars and four six-wheel truck cars showed lower resistance figures than when composed of eight four-wheel truck cars and two six-wheel truck cars. From the analysis of these and other tests made on the W. J. & S. R. R. it was concluded that the resistance of steel passenger cars at a given speed is a function of the weight and is practically independent of the arrangement of truck wheels and, therefore, the results obtained on the various trains in which the average car weight was the same have been plotted against the corresponding speed of the train over the test section.

60. The curve shown in Fig. 6 follows the formula

$$R = \frac{100}{W} + 1.5 + \frac{V\,(V+16)}{100\sqrt{W}}$$

in which

R = Resistance—Pounds per ton.
V = Velocity—Miles per hour.
W = Weight of car—Tons.

61. This formula has been taken from a report submitted to the Altoona Railroad Club in November, 1911, and with the proper values of car weight and velocity the curve in Fig. 6 has been drawn to show how the actual test results agree with this formula.

62. The *average* resistance from the test results is approximately 85 per cent. of that shown by the curve. However, in the resistance figures obtained from the formula ample provision is made in the locomotive loading for adverse conditions of cars, lubrication, wind, weather, etc., and therefore the curve may be considered as the *average maximum* resistance.

Comparative Resistance—Four-Wheel and Six-Wheel Trucks under Steel Cars.

63. In November, 1910, a series of tests was conducted on the W. J. & S. R. R. to determine the resistance of four-wheel truck steel passenger cars compared with steel cars having six-wheel trucks.

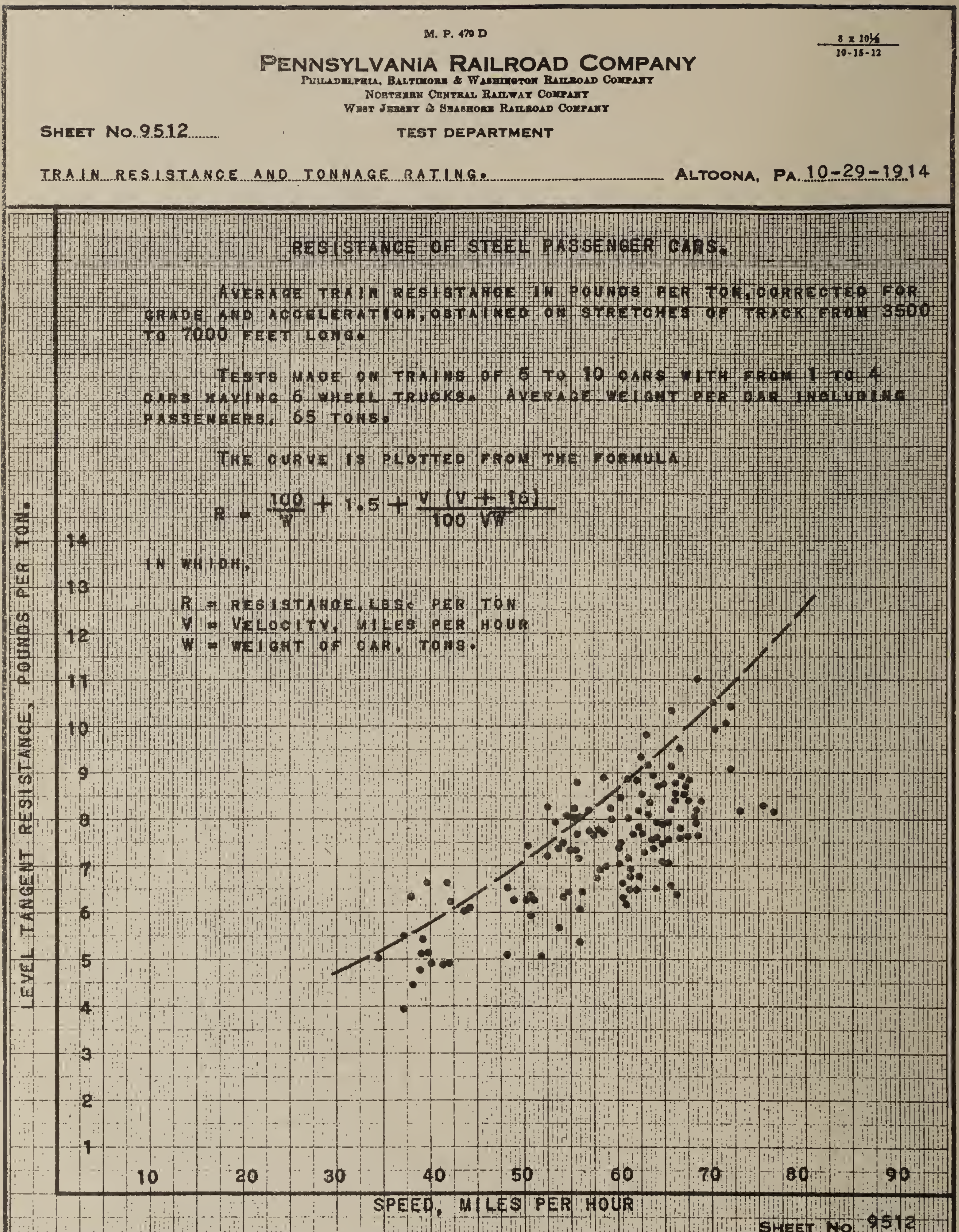

Fig. 6.

PASSENGER CAR RESISTANCE.

This diagram shows the level tangent resistance per ton for steel passenger cars. The average weight per car was 65 tons and is approximately equal to that of a class P-70 coach with passengers.

64. Two six-car trains were tested. One train was composed of P-70 passenger steel coaches having four-wheel trucks weighed 354 tons or an average car weight of 59 tons. The other train was made up of M-70 six-wheel truck postal steel cars. The weights of the car bodies of the M-70 cars were made equal to those of the P-70 cars by loading. The weight of the M-70 train was 397 tons or 66 tons per car.

65. The only difference between the weight of the trains was that due to the six-wheel trucks being heavier than the four-wheel trucks. Approximately uniform weather conditions prevailed during the tests of both trains.

66. The resistance was obtained over stretches of tangent track and correction for grade was made by averaging the results of northbound and southbound tests over the same stretch of track.

67. The results of these tests are shown in Fig. 7. The maximum, minimum and average results are as follows:

Speed in Miles per Hour	Resistance, Pounds per Ton for Cars with					
	Six-Wheel Trucks			Four-Wheel Trucks		
	Max.	Min.	Avg.	Max.	Min.	Avg.
34 to 36	4.41	4.09	4.30			
35¼ " 36½				6.10	5.60	5.80
50 " 50½	6.00	5.75	5.88			
51¼ " 53½				6.61	6.02	6.38
60 " 64¼	7.48	7.05	7.25			
62 " 67				9.20	8.40	8.82

68. These results show the inconsistencies which may arise in passenger train resistance, inasmuch as the six-wheel truck cars do not show a higher resistance than the four-wheel truck cars. On the contrary, due to the heavier trucks, the resistance in pounds per ton is less for the six-wheel trucks than for the four-wheel truck cars at all speeds.

69. In general it may be said that for all practical purposes there is little difference between the resistance of passenger cars of equal weight whether carried on four or six-wheel trucks. The supposition that for equal car weight the car having the greater number of journals should have the greater resistance is not sustained by the results of these tests.

Comparative Resistance—Wooden Cars and Steel Cars.

70. In Fig. 8 are shown the results of tests made in February, 1912, on the W. J. & S. R. R., to determine the comparative resistance of wooden and steel passenger equipment cars.

71. Two 10-car trains were tested, one of steel and one of wooden cars. Each train was made up of the dynamometer car, two baggage cars, three coaches and four Pullman cars. The steel train had a total weight of 627 tons and was carried on 48 axles. The average weight per car was 62.7 tons. The wooden train weighed 462 tons and was carried on 52 axles, the average weight per car being 46.2 tons. The weather conditions prevailing during the tests were approximately the same for both trains.

72. Two round trips were made with each train between Camden and Atlantic City, a distance of 60 miles, one trip at a nominal speed of 50 m.p.h. and one at 65 m.p.h. The resistance was computed from the dynamometer car record over a number of two-mile stretches of tangent track. A correction for grade was made by averaging the resistance over a stretch of track northbound with that shown over the same stretch southbound.

73. The full line curves shown in Fig. 8, representing the resistance in these tests, are somewhat lower than they would be if they were plotted from values obtained from the formula in Par. 60.

74. If these tests had been carried on over an extended period of time with different conditions of cars, weather, etc., it is probable that the average results would fall close to the dotted curves in which values equal to 85 per cent. of those shown by the formula are plotted.

75. The maximum, minimum and average results in Fig. 8 are as follows:

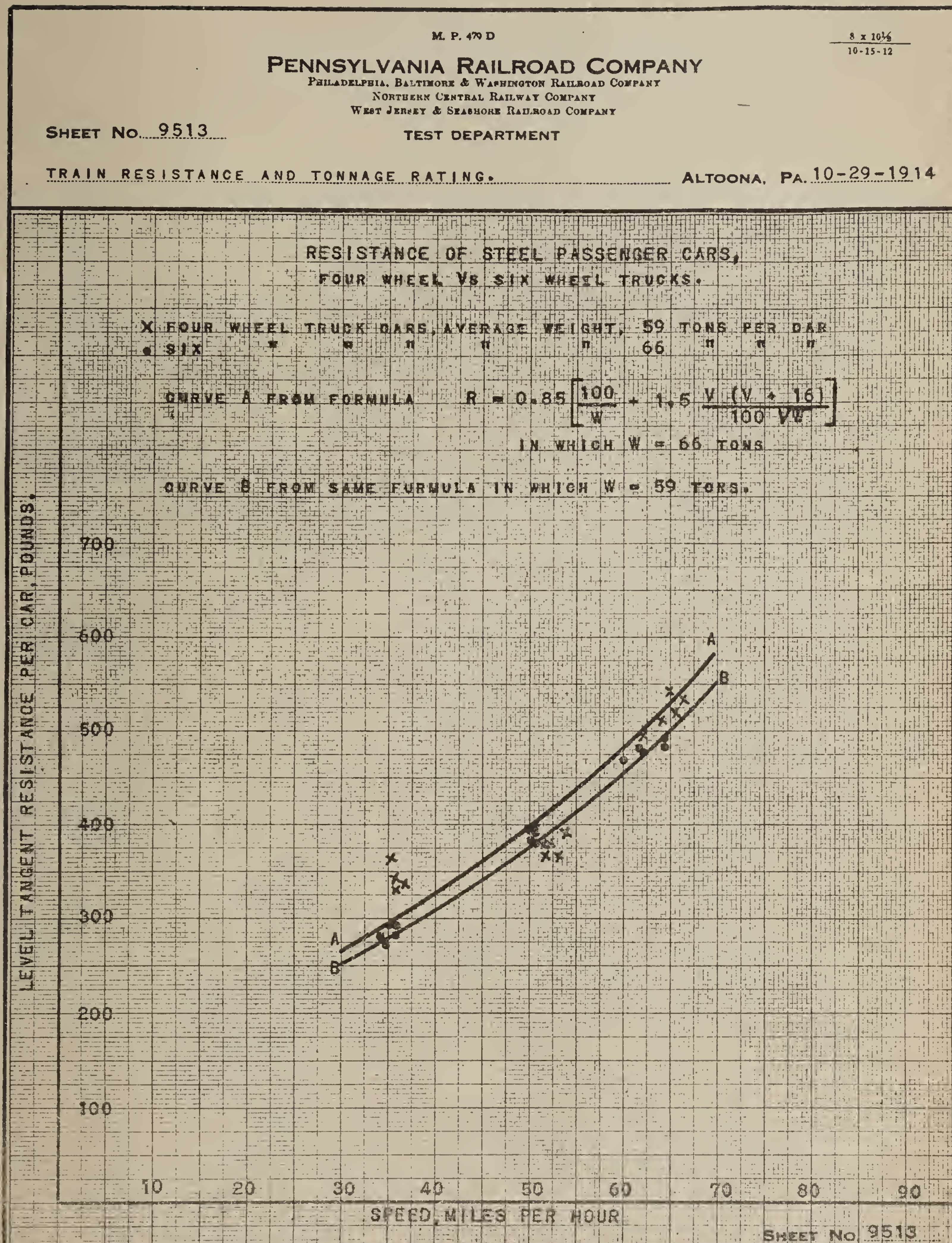

Fig. 7.

PASSENGER CAR RESISTANCE.

Four-Wheel vs. Six-Wheel Trucks.

With car bodies of equal weight there is little difference in the resistance whether carried on four or six-wheel trucks.

RESISTANCE—POUNDS PER TON.

Nominal Speed Miles per Hour		Wooden Cars, 46 Tons Each	Steel Cars, 63 Tons Each	Lower Resistance for Steel Cars in Per Cent.
50	Max.	6.87	6.16	10
	Min.	6.48	5.71	12
	Avg.	6.62	6.07	8
65	Max.	10.39	9.52	8
	Min.	9.35	8.83	6
	Avg.	10.07	9.13	9

76. A consideration of the relative carrying capacity of the two trains used in the tests, shows that, while the steel train was 36 per cent. heavier than the wooden train, it could have carried 27 per cent. more passengers. The increase in carrying capacity is due entirely to the P–70 steel coaches, the steel Pullman cars being approximately 39 per cent. heavier than the wooden Pullman cars, but with the same seating capacity.

77. A comparison of the weight and seating capacity of one of the latest types of wooden PK coaches and a steel P–70 coach is as follows:

	P–70 (Steel)	PK (Wooden)	Steel Cars	
			Increase Per Cent.	Decrease Per Cent.
Light weight, pounds	118,000	90,000	31.1	
Seating capacity	88	62	41.9	
Light weight per passenger, pounds	1340	1450		7.6

78. These tests have led to the following conclusions:

(*a*) On the basis of seating capacity the P–70 steel coach has a lower resistance than the PK wooden coach.

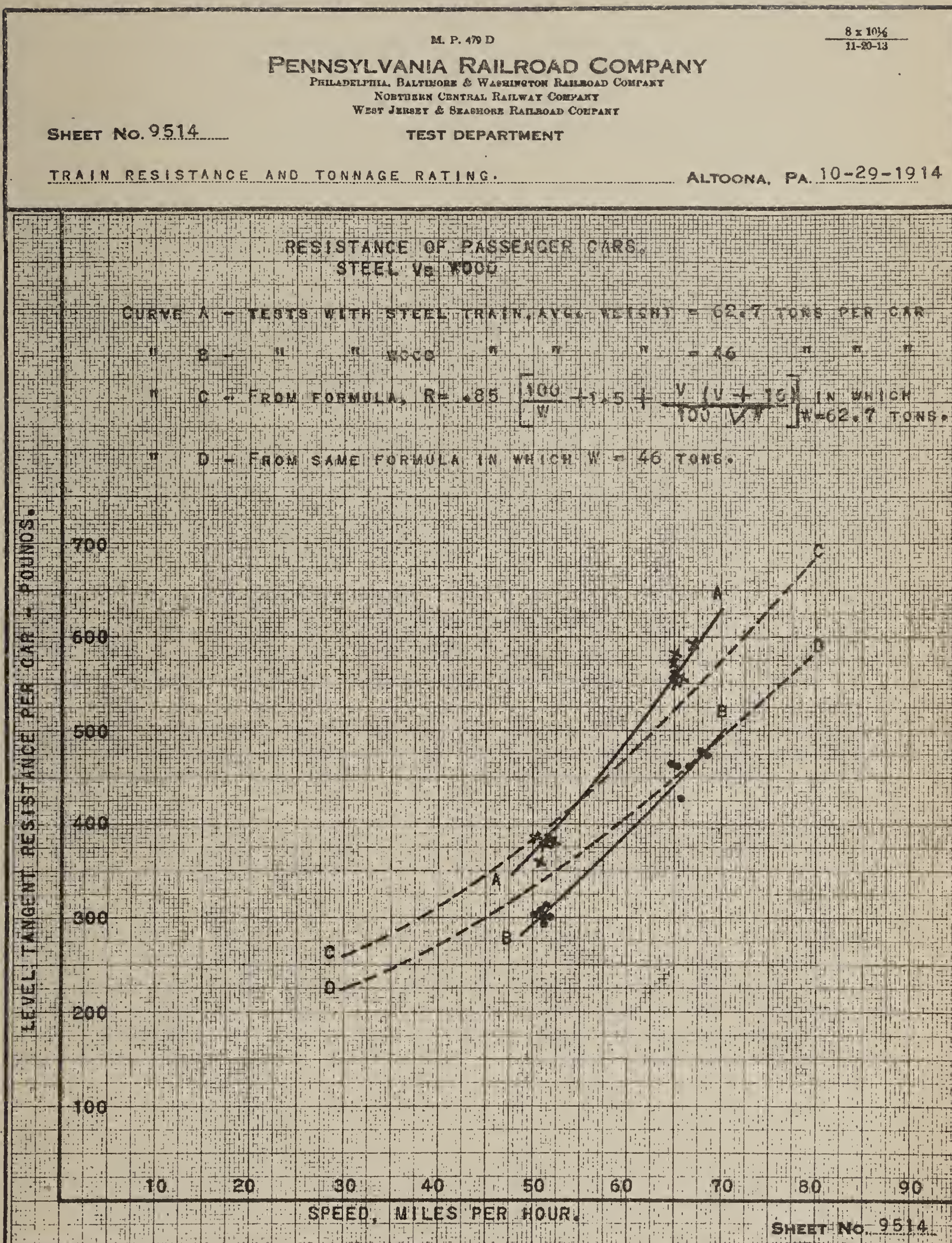

Fig. 8.

PASSENGER CAR RESISTANCE.

Wooden vs. Steel Cars.

The steel car has a greater resistance due to its greater weight.

(*b*) Based on the dotted curves (Fig. 8) the PK wooden coach has 18 per cent. greater resistance in pounds per ton than the P–70 steel coach.

(*c*) Steel cars have a greater resistance than wooden cars of the same type or capacity, due solely to the fact that the steel cars are heavier, that is, the increase in resistance is a function of the weight.

Resistance of Axle Generators.

79. No definite data is available on the resistance due to axle generators. Although it is assumed that the operation of an axle generator does increase the resistance of the car, it has been observed many times in passenger train tests that with other conditions as nearly alike as it is natural to find them, trains made up largely of axle generator cars have shown a lower resistance than trains made up of cars not so equipped, and the conclusion is that the resistance added by the generator is slight when compared with the other resistances. The ordinary variations in the latter make it difficult to determine with any degree of accuracy the resistance due to the axle generator.

80. At speeds of about 15 m.p.h. the theoretical resistance of an axle generator on Pennsylvania Railroad cars is equal to $\frac{1330}{V}$, and for Pullman cars is equal to $\frac{1730}{V}$ where V is the speed in miles per hour. Thus, at 60 m.p.h. the axle generator resistance on a Pennsylvania Railroad car will be 22.2 pounds, which is less than 5 per cent. of the total car resistance.

Resistance—Scooping Water.

81. The average resistances in scooping water from a track tank at various speeds are shown in Fig. 9. These figures were obtained in passenger train tests on the Lines West in 1911 and show a considerable variation in the resistance at different speeds, this variation being due principally to the variation in the condition of the scoop and the depth of immersion.

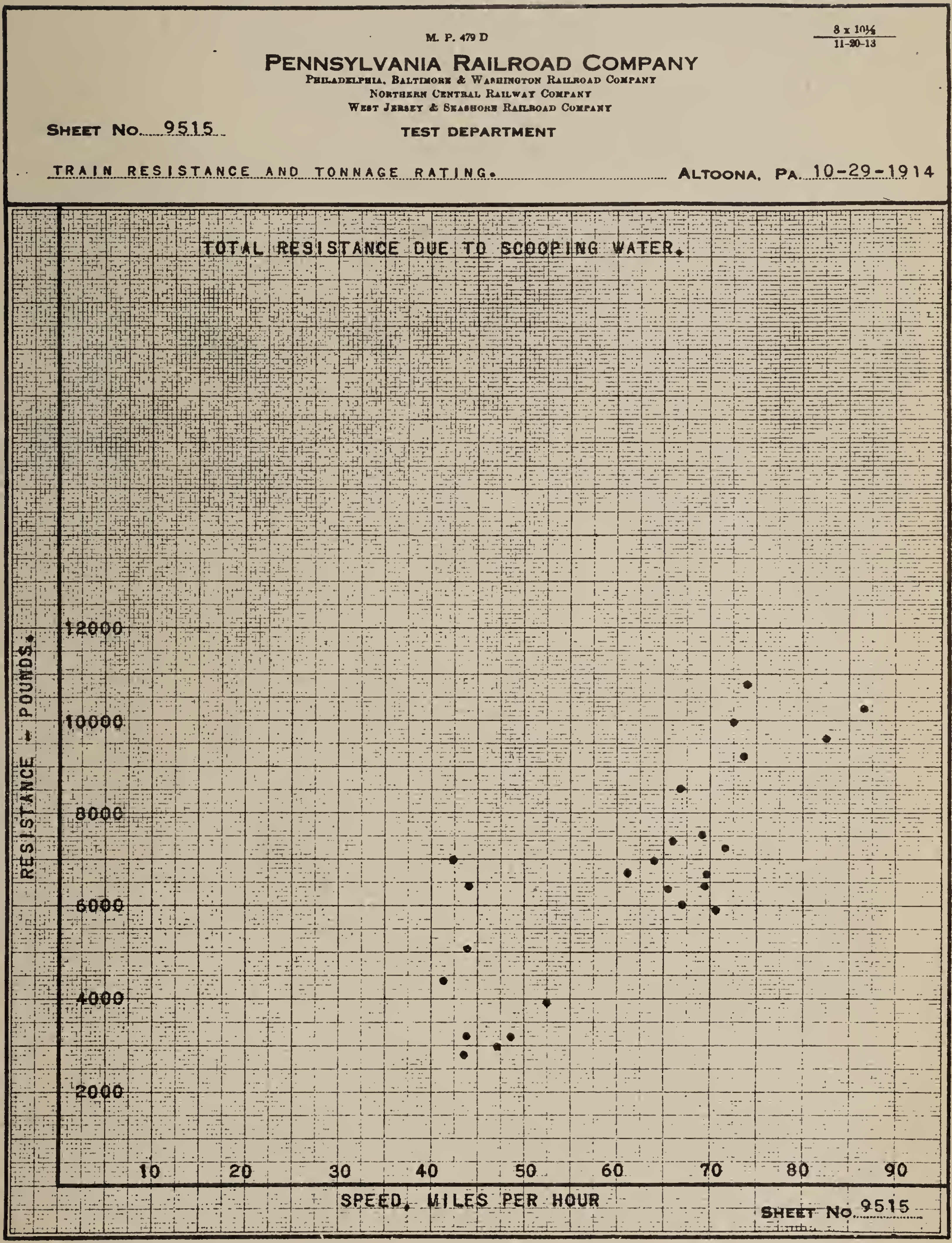

Fig. 9.

DRAWBAR PULL WHEN SCOOPING WATER.

The resistance due to scooping water depends on the condition of the scoop and the depth of immersion as well as the speed of the locomotive.

82. Fig. 10 shows the wave motion set up in the drawbar pull with a long train when scooping water at high speed. In general, this wave motion is more pronounced when only a short portion of the track tank is scooped as in the case shown, the scooping distance on this test being about 800 feet.

83. On this test the drawbar pull or train resistance, previous to putting the scoop in the trough was about 6000 pounds. As soon as the scoop was lowered the locomotive and tender pushed back against the train and overcame not only the train resistance but added a drawbar push of 4000 pounds. The total resistance due to scooping (10,400 pounds) was the resistance of the train added to the drawbar push of the tender during the time of scooping. The speed of the train was 73 miles per hour.

DRAWBAR PULL—FREIGHT LOCOMOTIVES.

84. The drawbar pulls at various speeds for the different classes of freight locomotives are shown in Fig. 11. Each of these curves represents the maximum drawbar pull which the locomotive can continue to exert within the capacity of the boiler to supply steam.

85. The curves shown are based on actual road tests and are representative of the drawbar pull of the given classes of locomotives when they are in average condition.

86. There are included in Fig. 11 curves for all of the locomotives now in general use on our lines for freight service.

The class L1s has, at 10 m.p.h., a tractive force 30 per cent. greater than that of its immediate predecessor the class H9s.

87. It should be noted that the curves shown in Fig. 11 apply to level tangent track. When operating on a grade, the available drawbar pull of the locomotive is influenced by the locomotive weight and the curves would be slightly different from those shown.

88. In Fig. 12 are shown the maximum drawbar pull curves obtained with Mallet locomotives No. 3396, class HH1s, and No. 3397, class CC1s. For comparison, the curves for classes H9s consolidation and L1s Mikado type locomotives are shown.

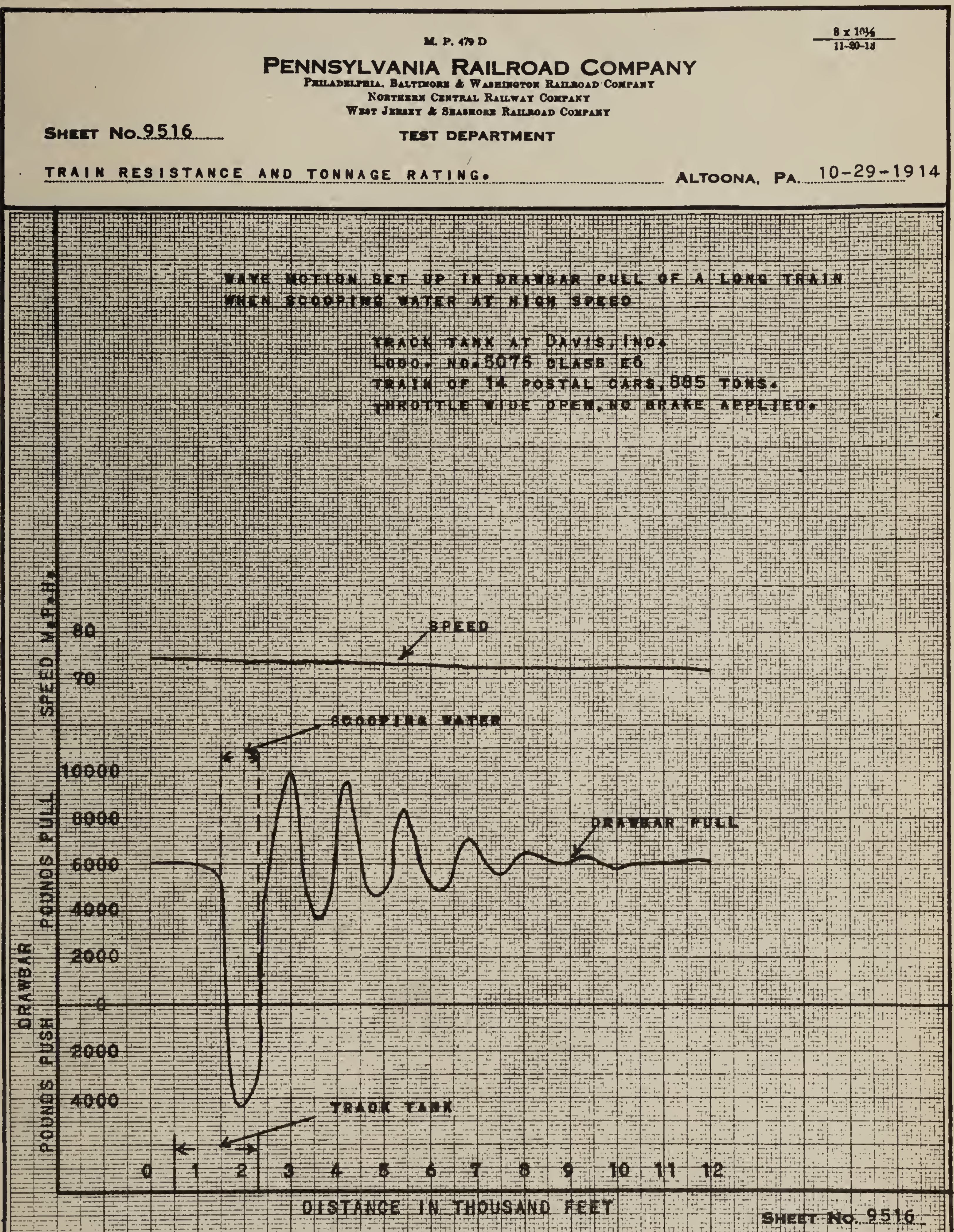

Fig. 10.

DRAWBAR PULL WHEN SCOOPING WATER.

A pronounced fluctuation is set up in the drawbar pull when water is scooped at high speed.

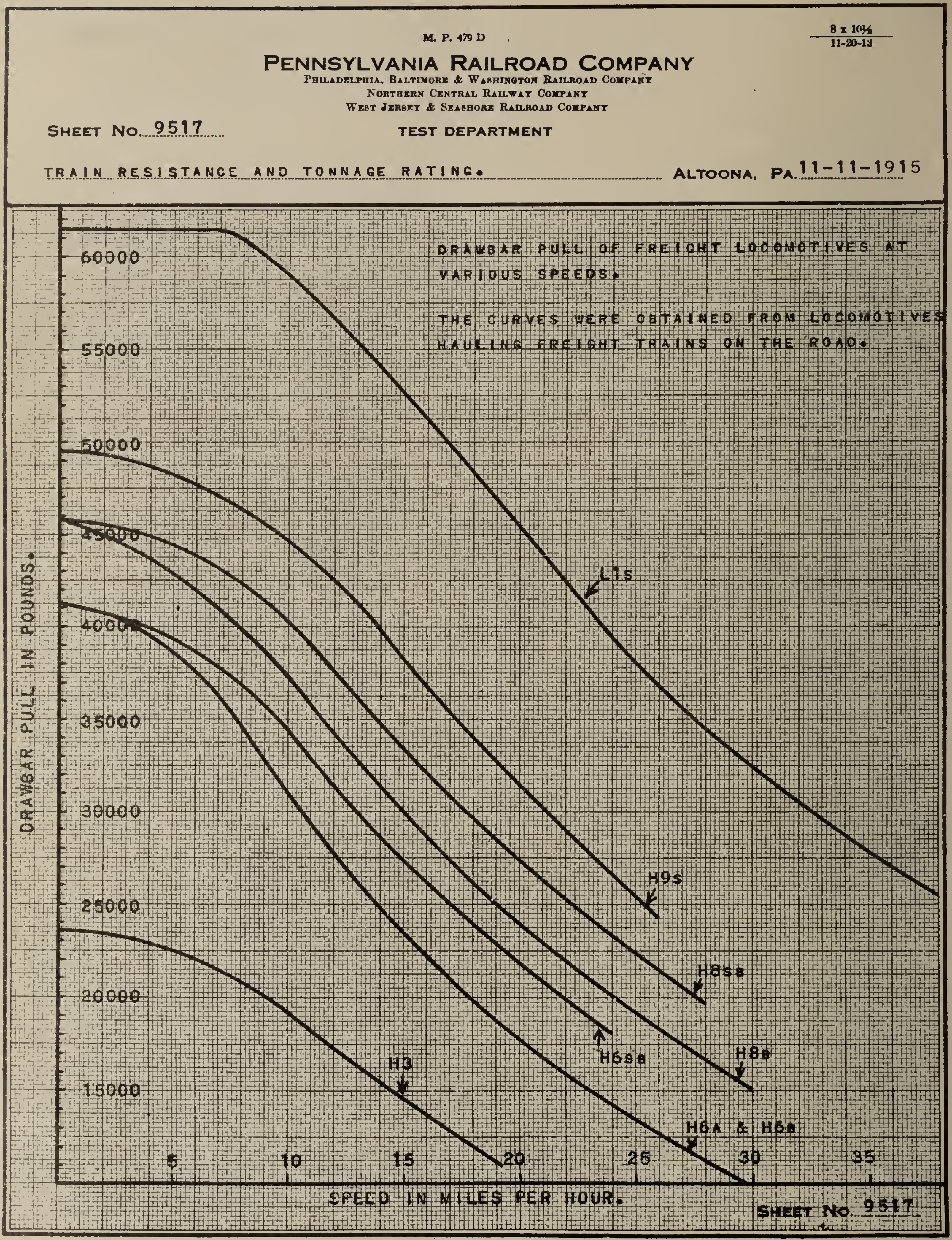

Fig. 11.

PULL SPEED CURVES.

FREIGHT LOCOMOTIVES.

At 10 m.p.h. the class L1s locomotives, built in 1914, show an increase in the drawbar pull of 204 per cent. over the class H3 locomotives, built in 1889.

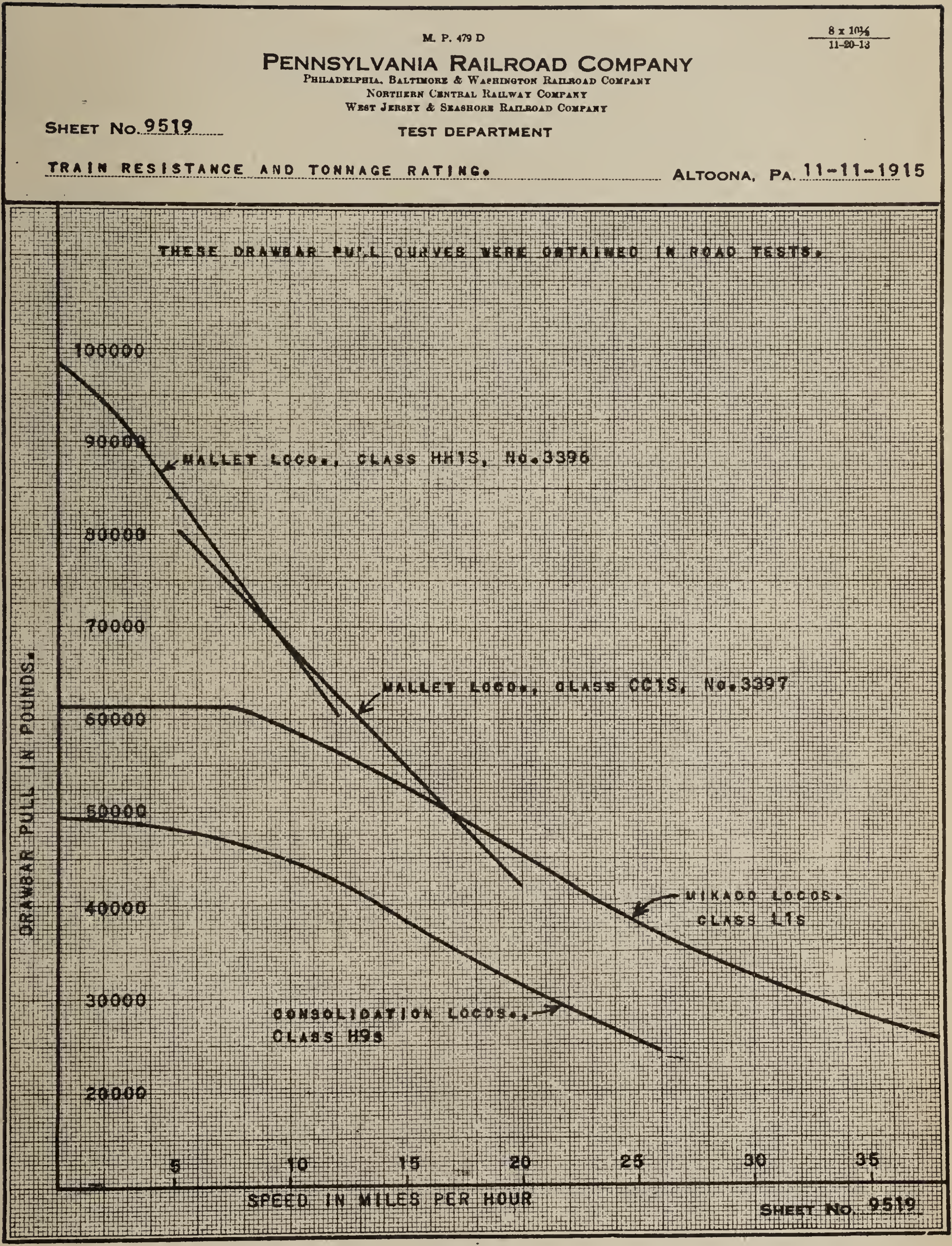

Fig. 12.

PULL SPEED CURVES.

FREIGHT LOCOMOTIVES.

At 7 miles per hour the Mallet locomotives have between 23 and 26 per cent. greater drawbar pull than the class L1s locomotives, but the pull of the mallets falls off so rapidly that at a speed between 14 and 17 m.p.h. it is no greater than that of the class L1s Mikados.

LOADING OF FREIGHT TRAINS—GENERAL.

89. There have been in use at various times four general methods of train loading, and these are as follows:

(*a*) Car loading.
(*b*) Straight tonnage loading.
(*c*) Drawbar pull loading.
(*d*) Adjusted tonnage loading.

The earliest of these is the car loading method, and it consists in assigning to locomotives of a certain class a fixed number of cars, regardless of the weight or capacity of the cars. This method would be entirely satisfactory if all cars were of the same size and weight. When a more efficient means of train loading was sought, straight tonnage loading came into use. This method consists in assigning to each class of locomotive a certain gross weight of train, regardless of the size and weight of cars, or whether loaded, partially loaded, or empty. Straight tonnage loading displaced the car method, as it had certain advantages, and it would seem that locomotives hauling trains of equal weight would need to exert equal drawbar pulls, but it was found that trains made up of fully loaded large cars could be hauled much easier than trains made up of the same weight of empty cars or the same weight of cars of small capacity.

90. Further modifications of train loading were sought to overcome these difficulties, and what is known as the drawbar pull method was introduced.

91. On a given track or division at a uniform speed, a locomotive has always the same capacity for pulling, or, as it is termed, the same drawbar pull. To load a train according to the drawbar pull method it is necessary to know the resistance of each weight of car. The known resistances for the cars are added up until the total resistance equals the locomotive drawbar pull. This method is accurate but inconvenient to apply and there appeared to be a need of a more simple method.

92. The adjusted tonnage loading of trains was then introduced to overcome the objection to the drawbar pull method. As adjusted tonnage loading is now in general use on our lines, it will be described.

Description of Adjusted Tonnage Method of Loading Freight Trains.

93. From dynamometer car tests on a large number of divisions and on cars of various classes, it has been found that for speeds from 5 to 25 miles per hour, the resistance of a 20-ton car on a level tangent track is 140 pounds, or seven pounds per ton, and for a 70-ton car 210 pounds per car, or three pounds per ton. Thus, although the 70-ton car is 3.5 times as heavy as the 20-ton car, the resistance of the former is only 1.5 times greater.

94. This comparatively slight increase in car resistance with the large increase in car weight is the factor which must be given consideration in order to obtain equal loading of locomotives when the trains they haul range between all loaded and all empty cars.

95. An illustration of how this variation in resistance with car weight may influence train loading is as follows: Let it be assumed that a locomotive of the H6a or H6b class, which has a drawbar pull of 30,700 pounds at 10 miles per hour on a level track, is operated on a 0.3 per cent. non-momentum grade at a speed of 10 m.p.h. The pull at the drawbar will be reduced by the effect of grade by an amount equal to 20 pounds per ton of locomotive weight, for each one per cent. ascending grade, or approximately a total of 1000 pounds, and therefore the available drawbar pull under these conditions will be 29,700 pounds. We will now consider three trains, the gross weight of each to be 3000 tons and the three trains to be made up as follows: One train having cars of an average weight of 20 tons, one train of cars of 40 tons and one train of cars of 70 tons.

96. The resistances, for cars of these weights, are as follows:

Weight Per Car, Tons	Resistance Per Ton, Pounds		
	Due to a Grade of 0.3 Per Cent.	On Level Tangent	Total
20	6	7.0	13
40	6	4.2	10.2
70	6	3.0	9.0

The drawbar pull necessary for each of these trains is equal to the gross tonnage multiplied by the total resistance per ton, or

A train of 20-ton cars requires	3000×13.0	or 39,000	lbs. drawbar pull.
" " " 40 " " "	3000×10.2	" 30,600	" " "
" " " 70 " " "	3000×9.0	" 27,000	" " "

The train made up of 20-ton cars would require a drawbar pull that is 31 per cent. beyond the capacity of the locomotive. The train of 40-ton cars would be 3 per cent. beyond its capacity, and the train of 70-ton cars would be an underload of 9.1 per cent.

97. The above analysis shows that to obtain equal loading of all locomotives of a class, the train load must be based on the resistance of the various cars making up the train, which resistance should equal the capacity in drawbar pull of the locomotive. Assuming that 29,700 pounds is the capacity of the locomotive, the gross tonnage of each of the above trains based on an equal drawbar pull is as follows:

$$\frac{29{,}700}{13} = 2290 \text{ actual tons.}$$

$$\frac{29{,}700}{10.2} = 2910 \quad \text{"} \quad \text{"}$$

$$\frac{29{,}700}{9} = 3300 \quad \text{"} \quad \text{"}$$

98. From the above it is apparent that if, as in Par. 96, the gross tonnage is used as the basis of train loading, there will be an inequality in locomotive performance, and if the loading is worked out for each train on the drawbar pull available, as in Par. 97, the method of loading is inconvenient to apply, especially when trains are made up of cars of various weights as is most frequently the case. It is therefore desirable to rate trains so that an equality of drawbar pull is obtained on all trains, regardless of the individual weights of the cars making up the train and, at the same time, have a tonnage figure or load the same for each train on a division. To obtain this equal loading, the actual gross tonnage is replaced by an "adjusted" tonnage to which all trains are loaded, this tonnage being such that the resistance or drawbar pull per "adjusted" ton is equal for all trains which are made up to be hauled by locomotives of a given class.

99. To obtain an adjusted tonnage which will satisfy the above requirements, let us assume that a constant quantity "K" tons will be added to the gross weight of each car. This quantity "K" will be called the adjustment or car factor. The adjusted tonnage for each of the cars of the weight assumed in Par. 96 will be 20+K, 40+K and 70+K. It follows that if the pull per "adjusted ton" is to be equal for various actual weights of cars

$$\frac{140}{20+K}=\frac{168}{40+K}=\frac{210}{70+K}$$

in which 140, 168 and 210 are the resistances on level tangent track for cars of 20, 40 and 70 tons, respectively, from which K=80 on level tangent track. However, when the grade and curvature conditions are taken into account, the value of the car factor "K" is affected and must be worked out on each division for the ruling grade or point on the line having the maximum resistance and governing the train load. When a proper value is obtained, an "adjusted" tonnage can be established which will satisfy the operating conditions governing the division.

100. An analysis of the method of determining the value of K suitable for various grades is as follows:

The resistance of freight cars of various weights on a level tangent track, as obtained in dynamometer car tests, is as shown in Fig. 4. The curve shows the resistance in pounds per car.

101. The equation of this straight line is

$$R=f_0\,w+c \qquad (1)$$

and this is the fundamental equation in tonnage rating.

The characters in this and the following equations are:

R = Total resistance of one car on a level tangent track in pounds.

Rg = Total resistance of one car on a grade of g per cent. in pounds.

w = Weight of one car in tons (2000 pounds).

W = Gross weight of train, excluding locomotive and tender, in tons.

K = Car factor or adjustment factor.

N = Number of cars in train.

g = Grade in per cent.

f_0 = A factor which has been found to be 1.4 on level tangent track. It includes the factors which are proportional to the weight of the car such as journal friction.

f = A factor which depends on the grade and equals $1.4+20g$. It represents the pounds drawbar pull per adjusted ton on a grade of g per cent.

c = A factor which depends on the value of f and K. On level tangent track it has been found to have a value of 112 (Fig. 4). On a grade the value of c, which includes the factors not appreciably affected by the weight of the car, such as flange friction, may vary somewhat, and the correct value can only be determined by actual tests.

102. The total resistance per car on a grade is equal to the level resistance plus 20 times the grade in per cent. times the weight of the car in tons or

$$Rg = f_0\ w + c + 20\ gw = w\ (f_0 + 20\ g) + c.$$

Letting $f_0 + 20\ g = f$, we have

$$Rg = f\ w + c \qquad (2)$$

Consider two trains as follows:

	First Train.	*Second Train.*
Number of cars	N	N_1
Weight per car (tons)	w	w_1
Gross weight of train (tons)	W	W_1
Adjusted tonnage	Wt	Wt_1

Assume that the first train has a small number of loaded cars and the second train a large number of empty or lightly loaded cars, and in each case the drawbar pull and total adjusted tonnage are equal, so that

$$Wt = W + KN = Wt_1 = W_1 + KN_1$$

$$W + KN = W_1 + KN_1$$

$$W - W_1 = K\ (N_1 - N)$$

$$K = \frac{W - W_1}{N_1 - N} \qquad (3)$$

In equation (2) $Rg = fw + c$
from which we have

$$Rg\ N = (fw + c)\ N$$

$$Rg\ N_1 = (fw_1 + c)\ N_1$$

RN and RN_1 being the drawbar pulls of the two trains and assumed equal as stated above.

Therefore:

$$fwN + cN = fw_1N_1 + cN_1$$
$$f\ (wN - w_1\ N_1) = c\ (N_1 - N)$$
$$\frac{c}{f} = \frac{wN - w_1\ N_1}{N_1 - N}$$

But,

$wN = W =$ Gross weight of first train (tons)

$w_1N_1 = W_1 =$ Gross weight of second train (tons)

Therefore: $\frac{c}{f} = \frac{W - W_1}{N_1 - N}$ .... (4)

From (3) and (4)

Car factor $= K = \frac{c}{f} = \frac{W - W_1}{N_1 - N}$ .... (5)

103. In order to determine the values of c and f for any particular grade, dynamometer car tests are made with trains of different average weights per car, i. e., trains of empty or lightly loaded cars and trains made up of fully loaded cars. The tonnage hauled on the tests is such that when the locomotive is worked to the limit of its capacity, the speed over the ruling grade is approximately that desired for operation in regular service.

104. The average drawbar pull as shown by the dynamometer record on the ruling grade is corrected for acceleration or retardation, the result being the average train resistance at constant speed on the grade.

105. This train resistance when divided by the number of cars gives the average pull per car, which pull is plotted against the average weight per car of the train in question. (Fig. 13.)

106. Through the mean of the points thus determined a straight line is drawn. This line may be represented by the equation $Rg = f\ w + c$, in which Rg equals the resistance in pounds per car, w is the weight of the car in tons, c is the intercept on the y-axis (112) and f the slope of the line $\left(\frac{952 - 112}{75}\right) = 11\ 2$ from which the car factor $K = \frac{c}{f} = 10$ or its value may be read direct from the intercept on the x-axis to the right of the origin.

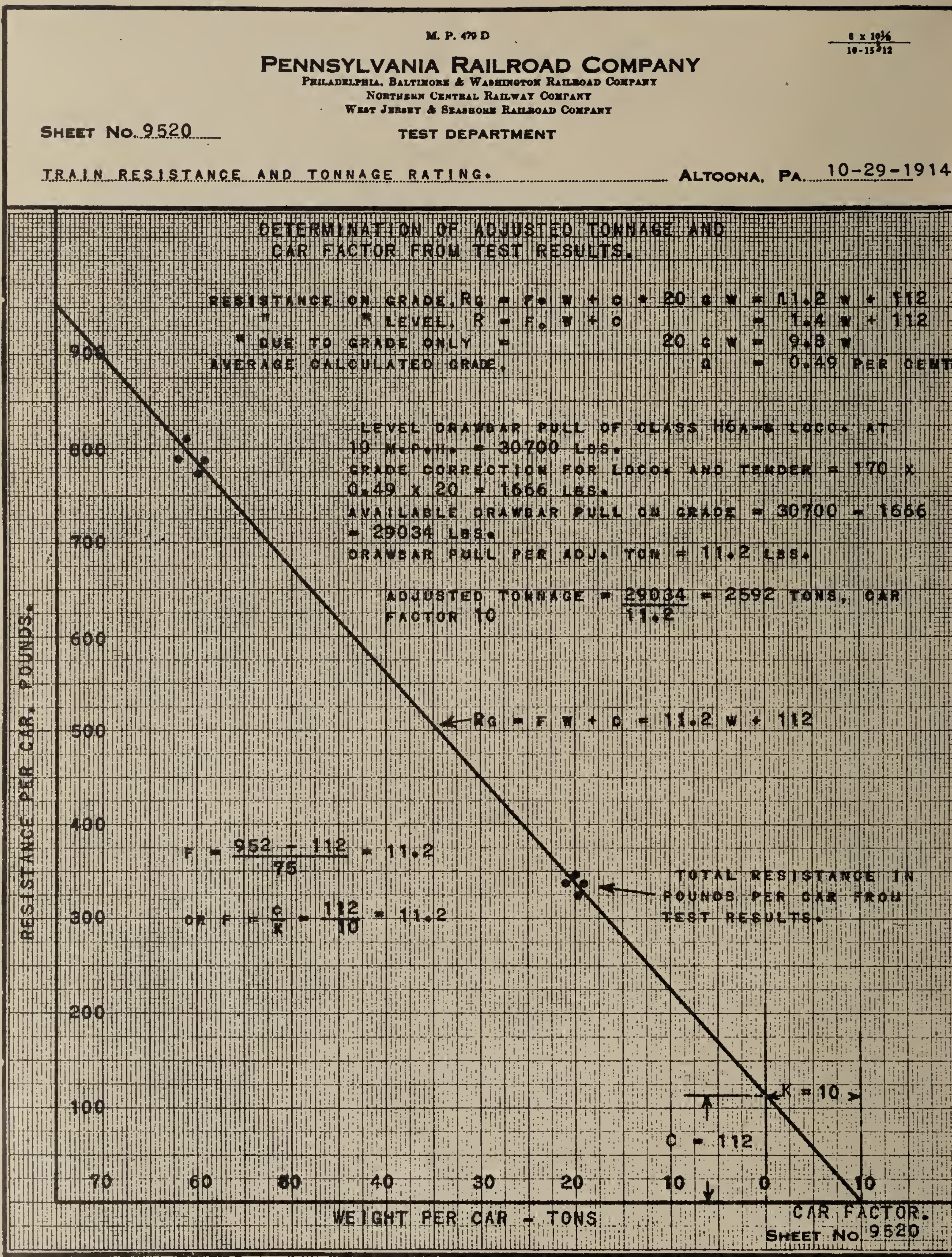

Fig. 13.

ADJUSTED TONNAGE AND CAR FACTOR.

This diagram shows the usual method of plotting results of dynamometer car tests over a ruling grade. The pull per adjusted ton is the tangent of the angle which the resistance line makes with the base line; in the case shown this is 11.2.

107. This method of determining the car factor can be applied to any grade condition and its value for any particular grade is taken the same for all classes of locomotives. Although special grade conditions may arise in which the car factor for trains hauled by locomotives having comparatively low drawbar pull may be different from that which would be found for long trains hauled by two or more locomotives of the same class or by locomotives of the Mallet type.

108. An illustration of this may be seen when we assume two trains of which the average weights per car are equal; one train is composed of 30 cars and is 1200 feet long, the other train is composed of 50 cars and is 2000 feet long. If now the length of the ruling grade is between 1200 and 2000 feet long, the average pull per car for the two trains will not be equal. This will be especially noticeable if the grade approaching the ruling grade is descending, whereupon a part of the long train will lie on the ruling grade and the remainder of the train on the approaching descending grade. It is evident that the average drawbar pull per car in the long train will be less than for the short train, and that the car factor obtained on grades of this character will depend on the class of locomotive used. In some instances it will be found that a short grade of this kind is the ruling point for short trains, while another grade or a curve on the division is the ruling point for long trains. The cases cited are uncommon and the determination of a suitable car factor for them must be given especial study.

109. For general practice, the value of the car factor will not be appreciably affected by the length of train hauled.

110. The value of f, obtained as explained in Pars. 102 and 106, is the pull per adjusted ton on the grade. If now it is desired to find the total adjusted tonnage which can be hauled by locomotives of a given class at a specified speed over the grade, the drawbar pull of the locomotive at that speed on level tangent track must be corrected for the effect of raising the locomotive up the grade and the drawbar pull thus available on the grade should be divided by the pull per adjusted ton. This grade correction is equal to 20 pounds per ton of locomotive and tender weight per one per cent. grade, thus the pull of a class H6a or H6b locomotive on level tangent track at 10 miles per hour is 30,700 pounds, if this

locomotive is working on a grade of one per cent., the available pull is 30,700—20 × 1 per cent. × weight of locomotive and tender, or approximately 27,300 pounds, the average weight of the locomotive and tender in this case being taken as 170 tons.

Method for Approximate Ratings by Calculation.

111. On those divisions where no tests have been made, the resistance per car on the ruling grade is calculated from the level tangent resistance, correction being made for the grade and alignment as shown by the track profile. The car factor and pull per adjusted ton is obtained from the plotted calculated results and the total adjusted tonnage for the various classes of locomotives is derived as explained in Par. 110. Another and shorter method of obtaining the same approximate results is as follows:

112. Suppose it is desired to know the adjusted tonnage which can be hauled by a class H6a or H6b locomotive up a one per cent. grade at a speed of 10 miles per hour. The available drawbar pull of the locomotive on the grade at 10 miles per hour, as explained in Par. 110, is 27,300 pounds.

113. The required pull per adjusted ton on the grade is $f = 1.4 + 20\,g = 21.4$ pounds.

114. The total adjusted tonnage is then obtained by dividing the available drawbar pull on the grade (27,300 pounds) by the pull per adjusted ton (21.4 pounds) which gives 1276 adjusted tons. The car factor K is equal to $\frac{c}{f} = \frac{112}{21.4} = 5.2$.

115. For convenience in using the results, the car factor may be taken as the whole number five and the adjusted tonnage 1276 tons without appreciable error. A train of this adjusted tonnage would be made up of $\frac{1276}{70+5} = 17$ loaded cars of 70 tons each, or $\frac{1276}{20+5} = 51$ empty cars of the same class of 20 tons each. Tonnages calculated in this way are but approximately correct inasmuch as local grade conditions may show the values of c and f to differ from the theoretical figures. It has also been assumed that the speed of approach to the foot of the grade and the speed on leaving the grade is the same, i. e., 10 miles per hour. In actual operation this condition seldom obtains, as most grades

are approached at a higher speed than is maintained on the grade. This condition must be given consideration in calculating tonnages, especially on short steep grades where the foot of the grade is reached at a comparatively high speed, which speed gradually decreases as the top of the grade is approached. Grades operated in this manner are known as momentum grades, over which much greater tonnages can be hauled than is possible where the speed is constant throughout the length of the grade. As a rule, however, no consideration need be given to the assistance which the locomotive receives from the drop in train speed when passing over grades of this character over 4000 feet in length; or when the speed of approach is 15 m.p.h. or less and the leaving speed eight miles per hour or more. In these cases the value of this momentum is slight and may be offset by the ordinary variation in pulling power of locomotives of the same class.

116. To illustrate the method of working out the adjusted tonnage when consideration is given to the momentum lost due to grade, suppose it is desired to know the number of adjusted tons which can be hauled by a class H6a or H6b locomotive on a one per cent. grade, 3000 feet long. Let it be assumed that the speed at the foot of the grade will be 20 miles per hour and the speed at the top of the grade eight miles per hour. This assumption precludes the possibility of a stop at or near the foot of grade on account of grade crossing, water tank, etc.

117. The energy made available by the decrease in speed of the train, and expressed as a decrease in train resistance, may be computed from the formula

$$A = \frac{70\ (V_1^2 - V_2^2)}{D}$$

in which

A = Decrease in resistance in pounds per ton.

V_1 = Speed in miles per hour at foot of grade.

V_2 = " " " " " " top " "

D = Length of grade in feet.

70 = Constant which includes 5 per cent. for rotative inertia of the car wheels.

Substituting the assumed values.

$$A = \frac{70\ (20^2 - 8^2)}{3000} = 7.84 \text{ pounds per ton.}$$

118. This value of A will be deducted from the resistance on the grade at constant speed obtaining as the resistance of the 20-ton cars, 27—7.84 = 19.16 pounds per ton or 383 pounds per car; and for the 70-ton cars, 23—7.84 = 15.16 pounds per ton or 1061 pounds per car.

119. These values of the resistance per car will then be plotted against the average car weight and the car factor (8) and pull per adjusted ton (13.5) obtained as explained in Par. 106.

120. In the foregoing it has been assumed that the speed of the locomotive at the foot of the grade is 20 miles per hour, decreasing to eight miles per hour at the summit. Accordingly, the drawbar pull of the locomotive at the foot of the grade will be comparatively low, gradually increasing, the speed of the locomotive decreasing as the grade is ascended. The average value of the drawbar pull as the grade is ascended should be known in order to determine the adjusted tonnage which can be hauled, the pull per adjusted ton being known from the plotted results (f = 13.5).

121. It may be assumed without appreciable error that the average speed ascending the grade will be approximately the average of the entering and leaving speeds, or from 12 to 14 miles per hour.

122. The level drawbar pull of a class H6a or H6b locomotive at a speed of 12 miles per hour is 27,800 pounds, deducting 3400 pounds for the effect of the grade on the locomotive drawbar pull leaves available 24,400 pounds for overcoming the resistance of the train. The adjusted tonnage which can be hauled will therefore be $\frac{24,400}{13.5} = 1810$ tons with a car factor of eight.

123. No arbitrary rule can be set up to govern the speed which tonnage trains should have over the ruling grade. It is evident that a train which passes over the ruling grade at a speed of eight miles per hour will consume more time in passing over the balance of the division than one whose speed on the ruling grade is 10 to 12 miles per hour, which train can, on account of lighter

tonnage, make better meeting points and lose less time in accelerating the train after stops at water tanks, sidings, etc. Local operating conditions, largely determine the speed for which the rating should be set.

124. It may be found on some divisions on which there are numerous curves that although the car factor and adjusted tonnage chosen give equal loading for all locomotives on the ruling grade, the average drawbar pull of long trains, made up of lighter weight cars on the balance of the division, is much in excess of that obtained with the same adjusted tonnage hauled in short trains of a heavier average weight per car. In this case the train of light weight cars would consume a much longer time in covering the balance of the division than the train of heavy cars, and, therefore, the proper car factor to choose would be based on the resistance obtained over a long portion of the division, 10 to 30 miles in length, rather than that shown for the ruling grade. If the car factor is determined by this condition, the rating may be set so that the desired time over the division will not be excessive for the long trains.

125. From the foregoing it will be seen that to establish a proper rating, due consideration must be given to all the factors which may exist on an entire division as well as on that portion of the division which determines the maximum train load.

Car Factor and Pull per Adjusted Ton on Various Grades.

126. The table on the following page shows the approximate car factor and resistance or pull per adjusted ton on non-momentum ascending grades of different percentages. These values are deduced from equations 2 and 5, Par. 102, in which the value of c is taken as 112.

It should be noted that the values are approximate only and may be materially different if actual tests are made on the grade in question. However, in the absence of test results, the above values may be used, and having the drawbar pull of the locomotive at the speed it is desired to operate on the grade, the total adjusted tonnage may be computed with reasonable accuracy.

Grade in Per Cent. (g)	Pull per Adjusted Ton (f)	Car Factor (K)
Level	1.4	80
0.05	2.4	46.6
0.10	3.4	33.0
0.20	5.4	20.7
0.30	7.4	15.1
0.40	9.4	11.9
0.50	11.4	9.8
0.60	13.4	8.3
0.70	15.4	7.3
0.80	17.4	6.4
0.90	19.4	5.8
1.00	21.4	5.2
1.10	23.4	4.8
1.20	25.4	4.4
1.30	27.4	4.1
1.40	29.4	3.8
1.50	31.4	3.55
1.60	33.4	3.35
1.70	35.4	3.16
1.80	37.4	3.00
1.90	39.4	2.84
2.00	41.4	2.70
2.20	45.4	2.47
2.40	49.4	2.27
2.60	53.4	2.10

127. In Figs. 14, 14-A and 14-B have been plotted the ratings which were established by dynamometer tests on the ruling grades of the various divisions of the Lines East of Pittsburgh. The pull per adjusted ton that was obtained in these tests is plotted according to the adjusted tonnage rating which was determined as proper for class H6a or H6b locomotives.

128. The curved line in the figures represents the calculated adjusted tonnage rating at a speed of 10 m.p.h. for various pulls per adjusted ton.

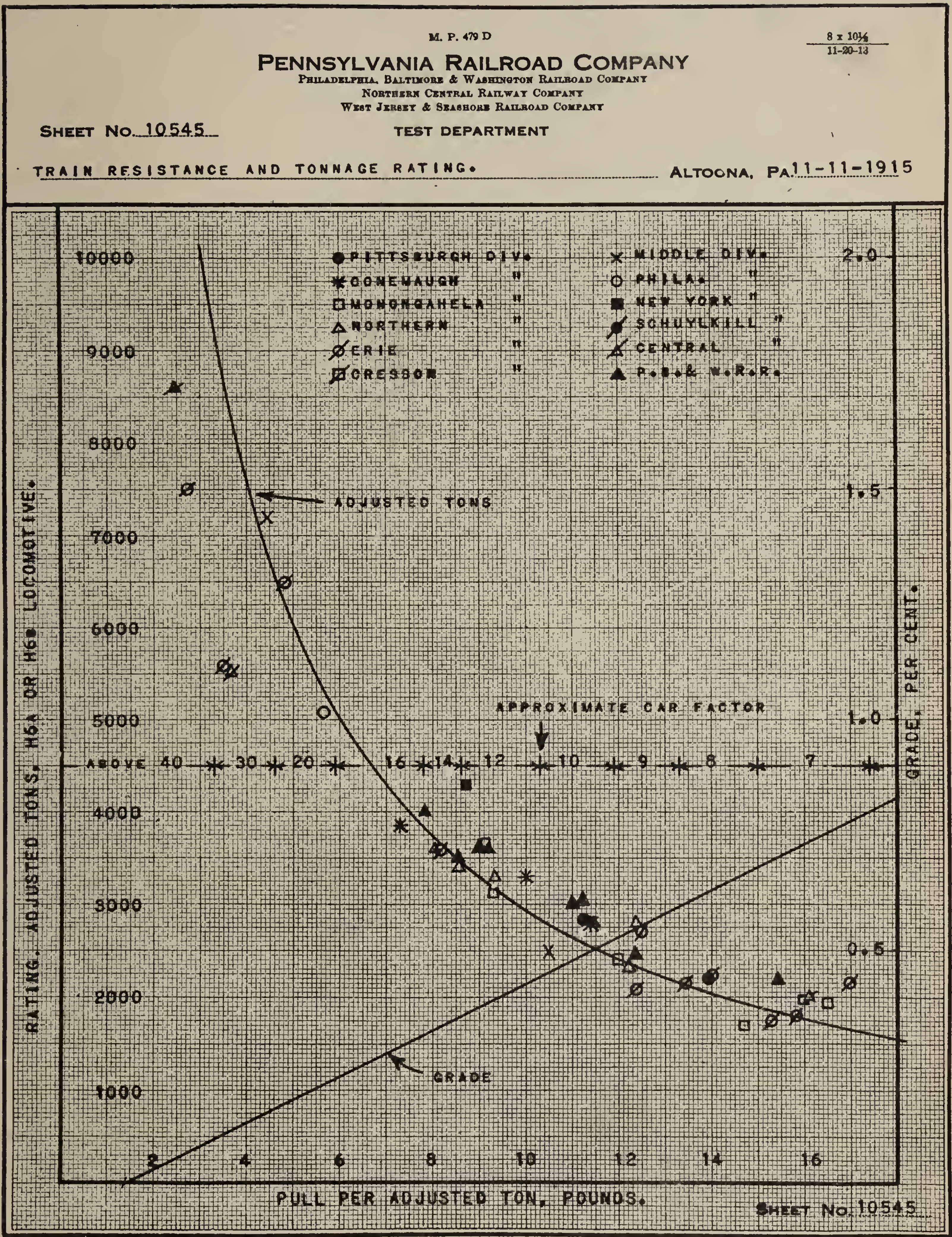

Fig. 14.

ADJUSTED TONNAGE RATINGS.

The tonnage rating and car factor for H6a or H6b locomotives are shown for 12 Penna. R. R. divisions. Figs. 14A and 14B are continuations of these curves.

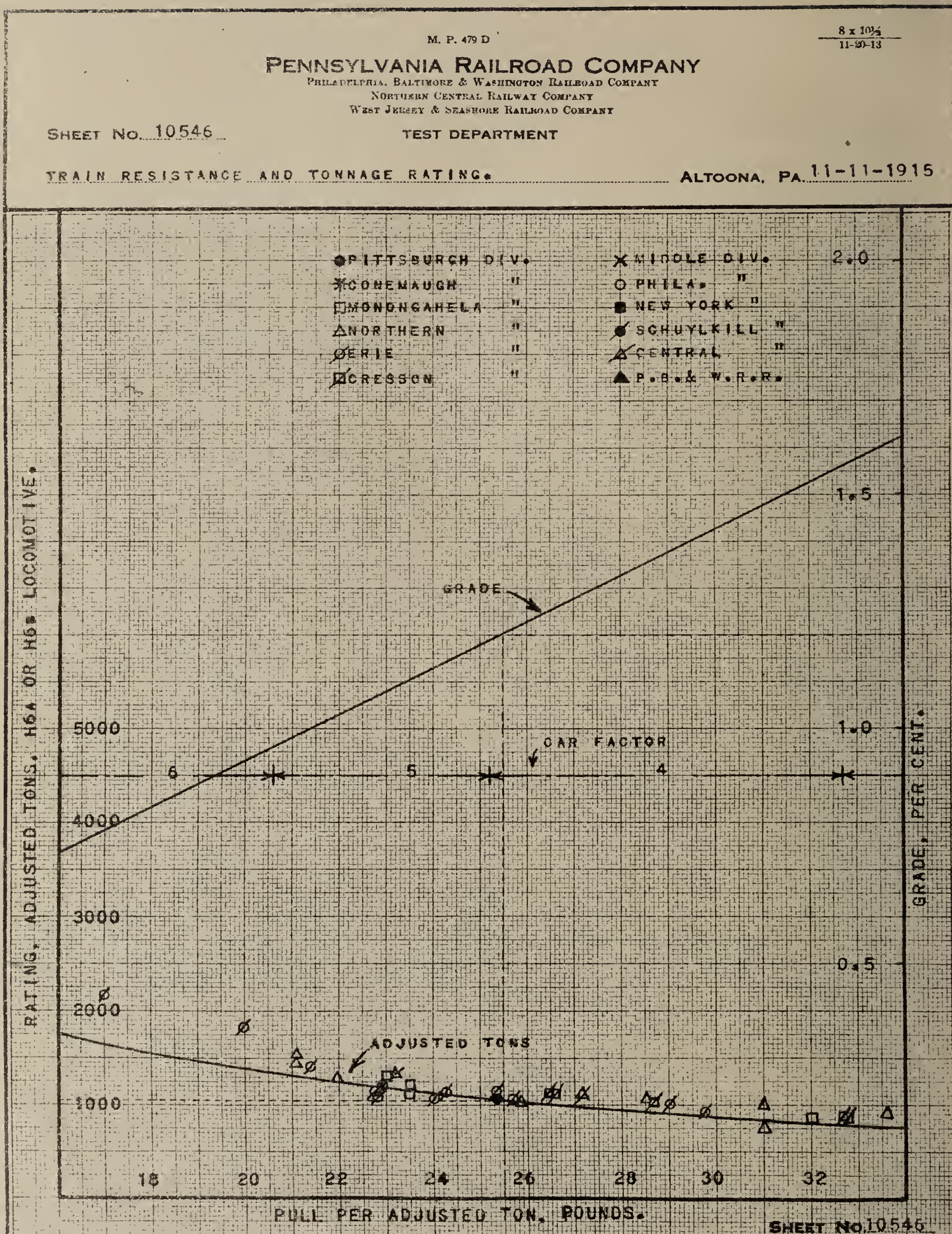

Fig. 14A (continuation of Fig. 14).
ADJUSTED TONNAGE RATINGS.

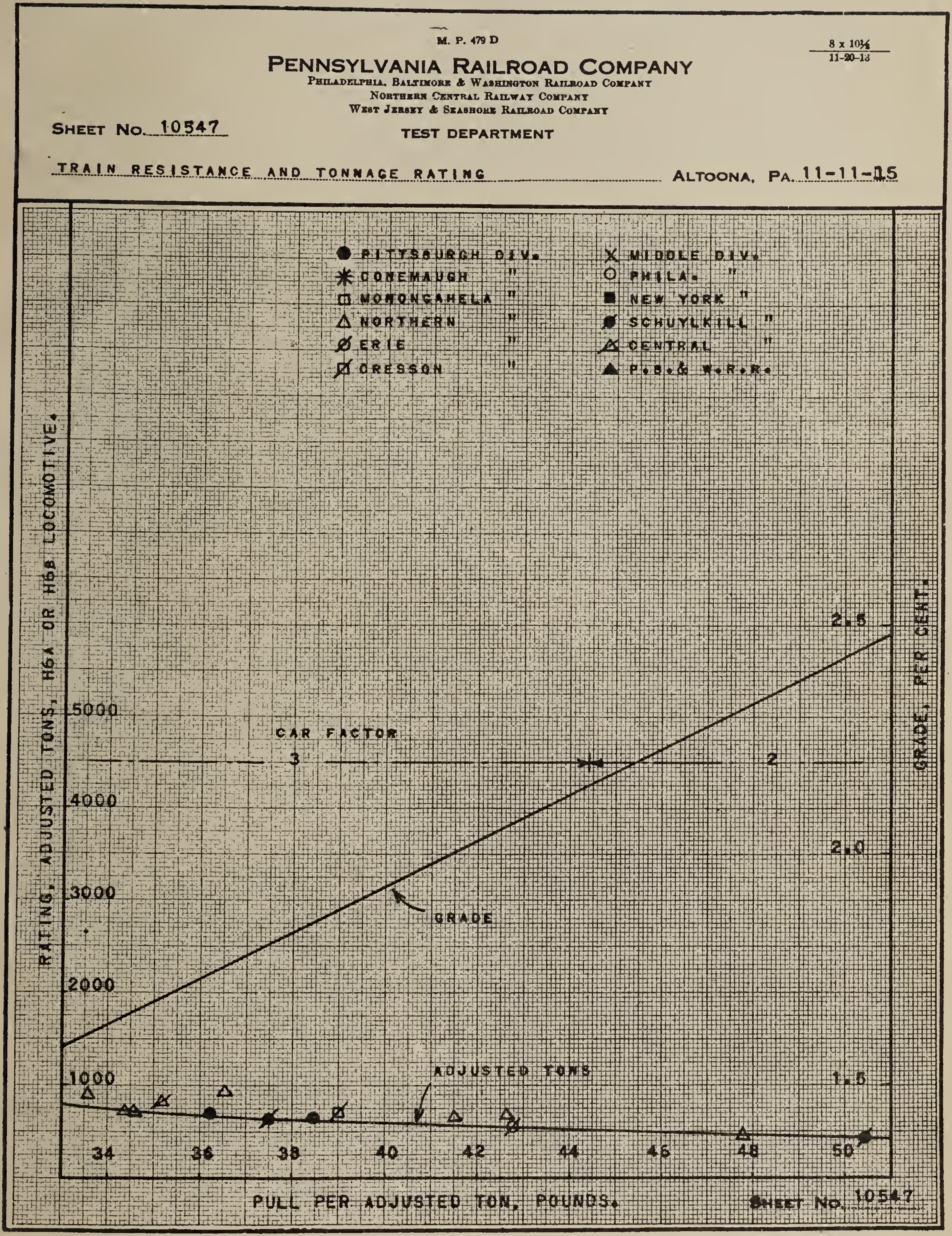

Fig. 14B (continuation of Fig. 14A).
ADJUSTED TONNAGE RATINGS.

129. The variations of the points from the curve are caused by certain operating conditions peculiar to the different grades, such as: the average speed on the grade was higher or lower than that upon which the curve is based; momentum operation of trains; ruling grade extremely long and allowance made for decreased locomotive efficiency. The grades corresponding to given pulls per adjusted ton are represented by a straight line.

130. The adjusted tonnage that can be handled by class H6a or H6b locomotive at a speed of 10 m.p.h. can be read from the diagrams as follows:

It will be assumed that the grade is 1.2 per cent. and for this condition the pull per adjusted ton, read on the bottom scale, is 25.5 pounds, Fig. 14-A. The corresponding adjusted tonnage is read on the scale to the left and is 1050. The car factor is 4.

Method of Approximate Ratings by Tests Without the Aid of a Dynamometer Car.

131. When a dynamometer car is not available to ascertain the actual hauling force of the locomotive and the resistance of the train, an approximate method may be used to determine the adjustment or car factor for loading trains and the maximum adjusted tonnage which a given locomotive may be capable of hauling.

132. This method necessitates the running of a number of test trains over the division or ruling section for which the tonnage basis is to be determined. These test trains may, for example, be composed, first of 140,000 pounds capacity cars, and second, of lighter weight cars such as 80,000 pounds capacity cars.

133. These two series of trains represent respectively the maximum weights of the shortest and longest trains which can be hauled by a given locomotive over the ruling point at a speed most suitable for the efficient operation of the road.

134. Having run several test trains of each make-up, the adjustment factor may be found as graphically shown in Fig. 15 where for each train the number of cars is plotted as abscissæ with the total gross tons hauled as ordinates. Each point thus plotted represents the make-up of a test train, as given in the following table and the straight line drawn through the plotted points is the basis for determining the actual adjustment factor per car.

DATA NECESSARY FOR APPROXIMATE TONNAGE RATING.

Test No.	Locomotive Class	Kind of Cars	No. of Cars	Weight of Train, Tons		Speed M.P.H.	
				Gross	Adjusted (Factor K=7)	Over Div.	Over Ruling Point
3	H6a	S	14	988	1086	8.5	6.6
5	H6a	S	14	987	1085	8.6	4.0
7	H6a	S	14	981	1079	9.0	2.6
43	H6a	S	14	1016	1114	10.6	6.0
45	H6a	S	14	1013	1111	9.1	4.5
47	H6a	S	14	998	1096	9.9	5.0
9	H6b	L	22	952	1106	9.6	3.3
11	H6a	L	22	932	1086	9.4	1.3
53	H6a	L	23	947	1108	8.4	4.0
57	H6a	L	22	944	1098	8.3	4.0
59	H6a	L	23	927	1088	9.4	1.0
61	H6a	L	23	941	1102	8.1	2.0

NOTE.—Train S composed of 100,000 lbs. capacity hopper and gondola cars. Train L composed of 50,000 lbs. and 60,000 lbs. capacity hopper and gondola cars. Grade at ruling point, 1.159 per cent.

Curvature at ruling point 6 deg. and 8 deg. for short train. Curvature at ruling point 7 deg. 45 min. and 5 deg. 49 min. for long train.

135. Thus, in Fig. 15, 10 spaces are laid off representing 10 cars and the ordinate indicates an adjustment of 69 tons or, dividing by the number of cars, $69 \div 10 = 6.9$ or 7 tons per car. It is observed that 14 cars or 998 tons represents the average weight of the maximum short trains. Therefore, they comprised $998 + (14 \times 7) = 1096$ adjusted tons.

136. The make-up of the long trains consisted of 23 cars or 936 tons, which with 7 as an adjustment factor, indicates a train of $936+(23 \times 7)=1097$ adjusted tons. The maximum adjusted tonnage which the given locomotive is thus capable of hauling for both long and short trains, is 1096 tons.

The computations may be expressed as below:

	Short Train	Long Train
Number of cars	N_S	N_L
Gross weight of train	W_S	W_L
Adjusted tonnage	W_{TS}	W_{TL}

K = car factor or adjustment factor.

$$\frac{W_S - W_L}{N_L - N_S} = K$$

$$W_S + (N_S \times K) = W_{TS}$$
$$W_L + (N_L \times K) = W_{TL}$$

Substituting the assumed values we have:

$$\frac{998 - 936}{23 - 14} = 6.9$$

Taking the whole number 7 as a convenient car factor to use, we have:

$$998+(14 \times 7)=1096 \text{ adjusted tons}$$
and
$$936+(23 \times 7)=1097 \text{ adjusted tons}$$

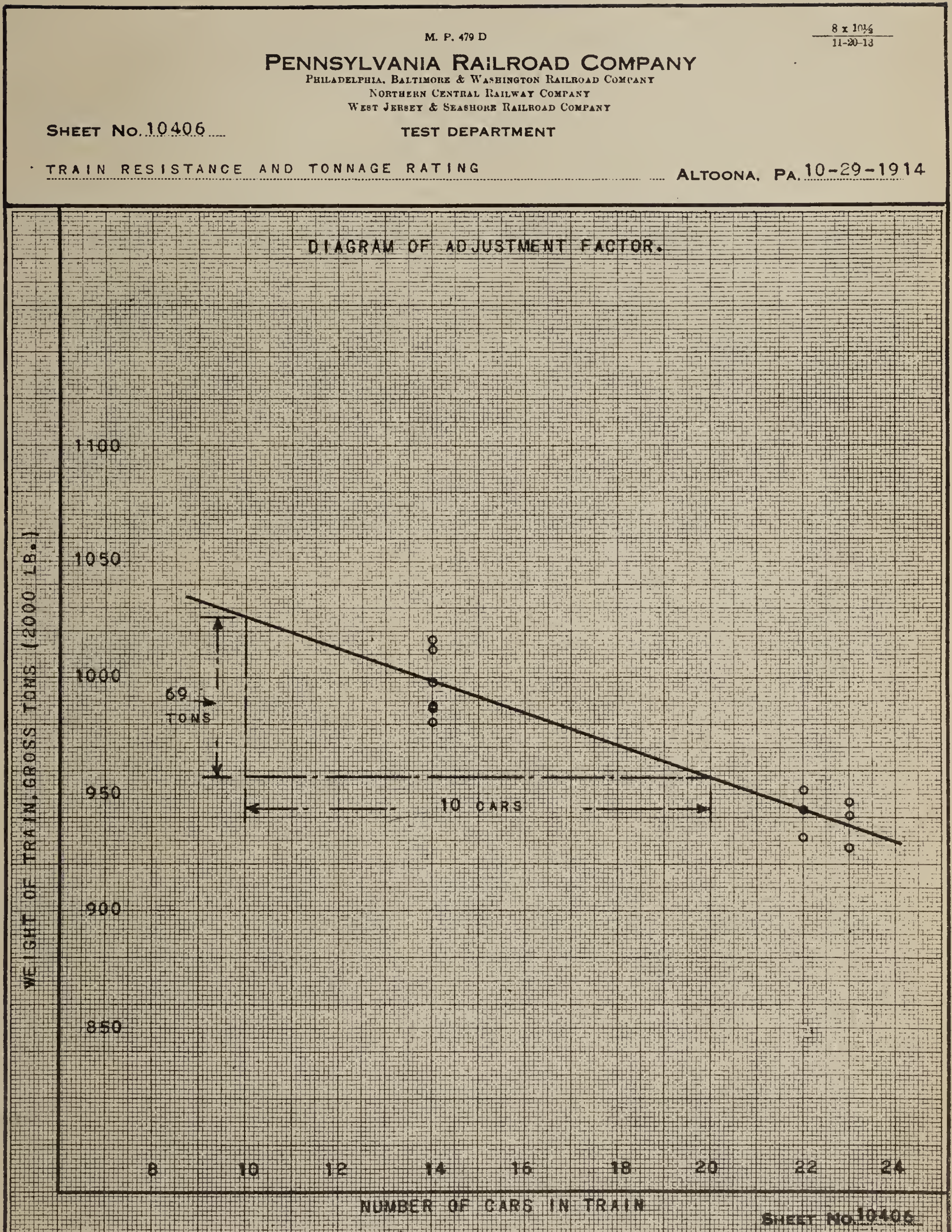

Fig. 15.

DIAGRAM OF ADJUSTMENT FACTOR.

The adjustment or car factor as obtained from the diagram is 69÷10. This is taken as the whole number, 7 and 1000 adjusted tons is recommended for a class H6a locomotive over this ruling point.

Winter Tonnage Rating.

137. During the tests on the Philadelphia Division Low Grade Line in 1907, it was found that the resistance of the trains, in pounds per ton, reduced to that for a level tangent, increased as the trains ascended the 25-mile Cresswell grade. See Fig. 5. This was clearly a temperature effect, although the tests were made in mild weather with temperatures above 45 degrees Fahr. The effect was noticeable even during days when the temperature was above 70 degrees Fahr., and is accounted for by the fact that these trains were run from Enola to the foot of the grade (about 35 miles) at an average speed of 20 m.p.h., and when beginning to ascend the grade the speed immediately fell to 10 m.p.h., and the journals commenced to cool down. The journals reached their minimum temperature near the top of the grade; and it was at this point that the highest resistance occurred.

138. In Fig. 16 are shown the results of tests made in the winter of 1912. In this diagram no attempt is made to show the increase in resistance with the drop in temperature, but the diagram is presented to bring out the fact that journal temperature depends to a great extent on the speed of the train. The temperature of the journal increases until the rate of heat production in the bearing equals the rate at which the heat is dissipated. At this point the bearing temperature becomes constant and the resistance reaches its minimum value. The heat dissipation is accomplished by the air moving over the journal box, wheel and axle. The rate of dissipation varies with the difference between the temperature of the bearing and the surrounding air, and therefore at a given rate of heat dissipation the journal temperature at a given speed is lower and the minimum viscosity of the oil greater in cold weather than in warm weather.

For these reasons the minimum resistance obtained in cold weather is greater than in warm weather.

139. The temperature below which this effect is most noticeable is about 40 degrees, judging from the practical results obtained by operating officials in their efforts to adjust tonnage ratings to suit temperature conditions.

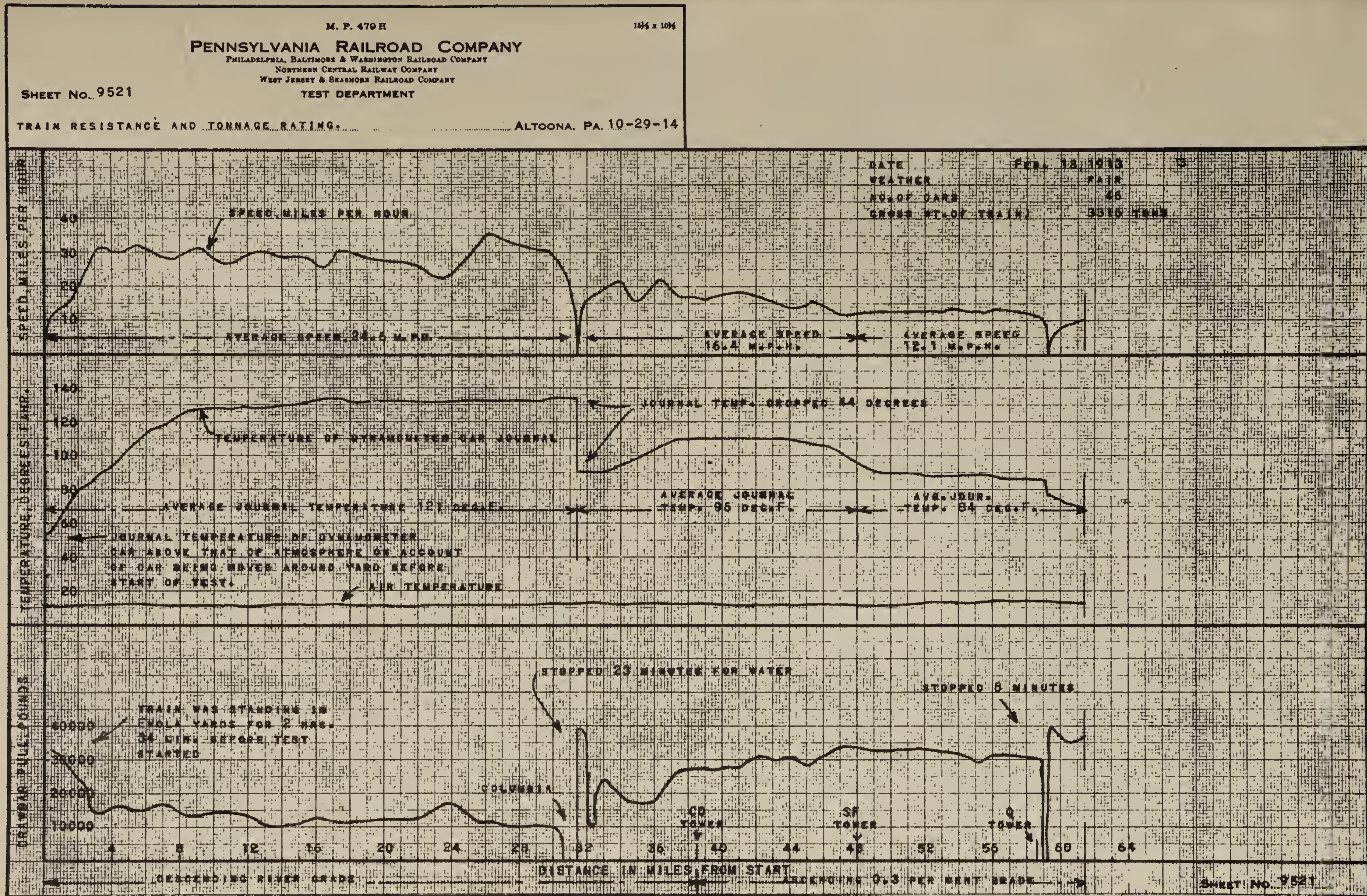

Fig. 16.

RELATION OF JOURNAL TEMPERATURE TO SPEED.

When the ascending grade is reached and the speed drops, the temperature of the car journals decreases. The temperature of the dynamometer car journal was taken by means of a thermo couple which was inserted in one of the journal brasses.

140. No data are available from which the relation of train resistance to outside temperature can be determined, and from the very nature of the factors which influence journal temperature it is impossible to assign fixed values for which the car resistance at any given temperature can be obtained. These factors are dependent on variable conditions to which the trains are subjected on a division; thus a certain train may be started from a terminal without any trouble owing to the easy grade and the rapid increase in speed, warming the oil in the boxes. After running for some miles from the start the journals may be at nearly as high a temperature as in summer weather and the oil may be flowing freely. If now the train takes a siding and stands long enough for the boxes to cool to outside temperature, a great increase in resistance may be expected and the grade conditions after passing this siding may be such that the journals cannot be warmed up before a grade is reached upon which the train, with the car journals cold, will stall.

141. The following figures obtained on the Low Grade Freight Line show the increase in resistance due to the cooling of the car journals at a stop. These figures are based on level tangent track and were obtained on the sections of track adjoining SF and Q Towers (Fig. 5). The average weight of the cars making up the trains was 72 tons.

EFFECT OF A STOP IN INCREASING RESISTANCE.

Speed Miles per Hour		Air Temp. Degrees	Resistance Lbs. per Ton		Increase in Resistance, in Per Cent.	Time Standing Minutes	Temperature of Dynamometer Car Journal While in Motion Degrees F.	
Approaching Tower	Beyond Tower		Before Stop	After Stop			Before Stop	After Stop
			Stop at Q Tower					
13.5	8.2	12	4.05	4.75	18	8	86	70
			Stop at SF Tower					
12.8	7.1	20	3.26	4.05	21	14	101	74
14.0	10.0	29	2.99	3.27	10	14	105	83
10.0	10.0	70	2.99	3.05	2	10 to 15	....	....

142. The following table shows the resistance in pounds per ton for cars of 72 tons weight over the same stretch of track and at different air temperatures. The speed on these tests was from 10 to 12 miles per hour, taken on a 0.3 per cent. grade, the figures given, however, are based on level tangent track.

TANGENT BEYOND SF TOWER.

(Trains stopped at SF Tower.)

Resistance Pounds per Ton	Air Temperature Degrees	Increase over Summer Resistance in Per Cent.	Time Standing at Tower Minutes
3.05	70	....	10 to 15
3.27	29	7.2	14
4.05	12	32.0	14

TANGENT APPROACHING Q TOWER.

(No stop made during the preceding hour.)

Resistance Pounds per Ton	Air Temperature Degrees	Increase over Summer Resistance in Per Cent.	Time Standing at Tower Minutes
3.17	70	....	....
3.21	29	1.6	....
3.68	20	16.0	....
4.05	12	28.0	....

TANGENT BEYOND Q TOWER.

(No stop at Q Tower.)

Resistance Pounds per Ton	Air Temperature Degrees	Increase over Summer Resistance in Per Cent.	Time Standing at Tower Minutes
3.20	70	....	....
3.36	29	5.0	....
3.69	20	15.3	....

On the tangent after passing SF Tower the car journals were not up to normal running temperature on account of the stop made at the tower. The figures given for the tangents, before and after passing Q Tower, were obtained after the train had been in motion for one hour at an average speed of 10 m.p.h.

143. From the foregoing it is evident that the proximity of the operating stops to the heavy grades on a division have an important bearing on the amount of reduction in tonnage which should be made in cold weather.

144. Three methods by which a reduction in train load may be made for cold weather are shown in the following table:

METHODS FOR REDUCING TONNAGE IN COLD WEATHER.

ELEMENTS INVOLVED IN TONNAGE RATING	METHOD A	METHOD B	METHOD C
CAR FACTOR	SAME AS IN SUMMER	INCREASED	INCREASED
Resistance per car..	Constant increase in percentage for all weights of cars.......	Constant number of pounds increase for all weights of cars......	Increased in inverse proportion to the weight of the car.
Drawbar pull of locomotive...........	Same as in summer.......	Same as in summer.......	Less than in summer.
Pull required per adjusted ton.......	Increased..........................	Same as in summer.......	Less than in summer.
Total adjusted tonnage.......................	Percentage reduction from summer rating........................	Same as in summer.......	Same as in summer.

145. No test results are available to determine definitely which of the above methods gives correct results. The methods B and C involving the use of a variable car factor, if carefully adhered to, would, in cold weather, render necessary a change in the factor many times a day and the possible use of fractional car factors.

146. It is evident that the use of a constant car factor (method A) for all weather conditions and a percentage reduction in the adjusted tonnage to provide for various air temperatures is the most practical. Obviously this percentage reduction for a given temperature cannot be the same on all divisions and can be satisfactorily made only when the operating conditions on a division are carefully considered.

147. The present practice on the Pennsylvania Railroad in winter ratings is to reduce the total adjusted tonnage as hauled in summer weather and maintain a constant car factor for all weather conditions. The percentage by which the total adjusted tonnage is cut to suit the weather conditions is shown in the following table, which is an average of the practice on 13 different divisions:

AVERAGE TONNAGE REDUCTIONS ON 13 DIVISIONS.

TEMPERATURE RANGE, DEGREES FAHR.	REDUCTION BELOW SUMMER RATING, PER CENT.
45—35	6
35—25	13
25—15	18
15— 5	26
5— 0	33

Storm Rating..45

148. On nine of the divisions represented in the above averages no cut is made in the tonnage until the temperature drops below 45 degrees. Two divisions make a cut when the temperature drops below 40 degrees. One division makes a cut in tonnage when the temperature falls below 30 degrees, and one division when the temperature drops below 25 degrees.

149. The probable increase in level tangent resistance at different air temperatures is shown in Fig. 17. One of the curves is derived from the tests made on the Low Grade Freight Line (Par. 138), and is based on the level tangent resistance after the train had been running for approximately one hour at an average speed of from 8 to 10 miles per hour. Although no tests were made below a temperature of 12 degrees Fahr., the indications are that at zero degrees there would be an increase in train resistance of about 50 per cent. In this same figure is shown the increase in train resistance based on the average tonnage reductions, which are made on 13 divisions of the Pennsylvania Railroad. It should be noted, however, that in this curve no allowance is made for the grade conditions on these different divisions. The reduction in tonnage on account of temperature on a division on which the grades are comparatively easy will be greater than on a division of heavy grades, for the reason that the grade resistance of itself has a constant value for all temperatures and on heavy grades forms a larger proportion of the total train resistance, whereas, on comparatively level track, the resistance due to low temperature forms a large proportion of the total train resistance.

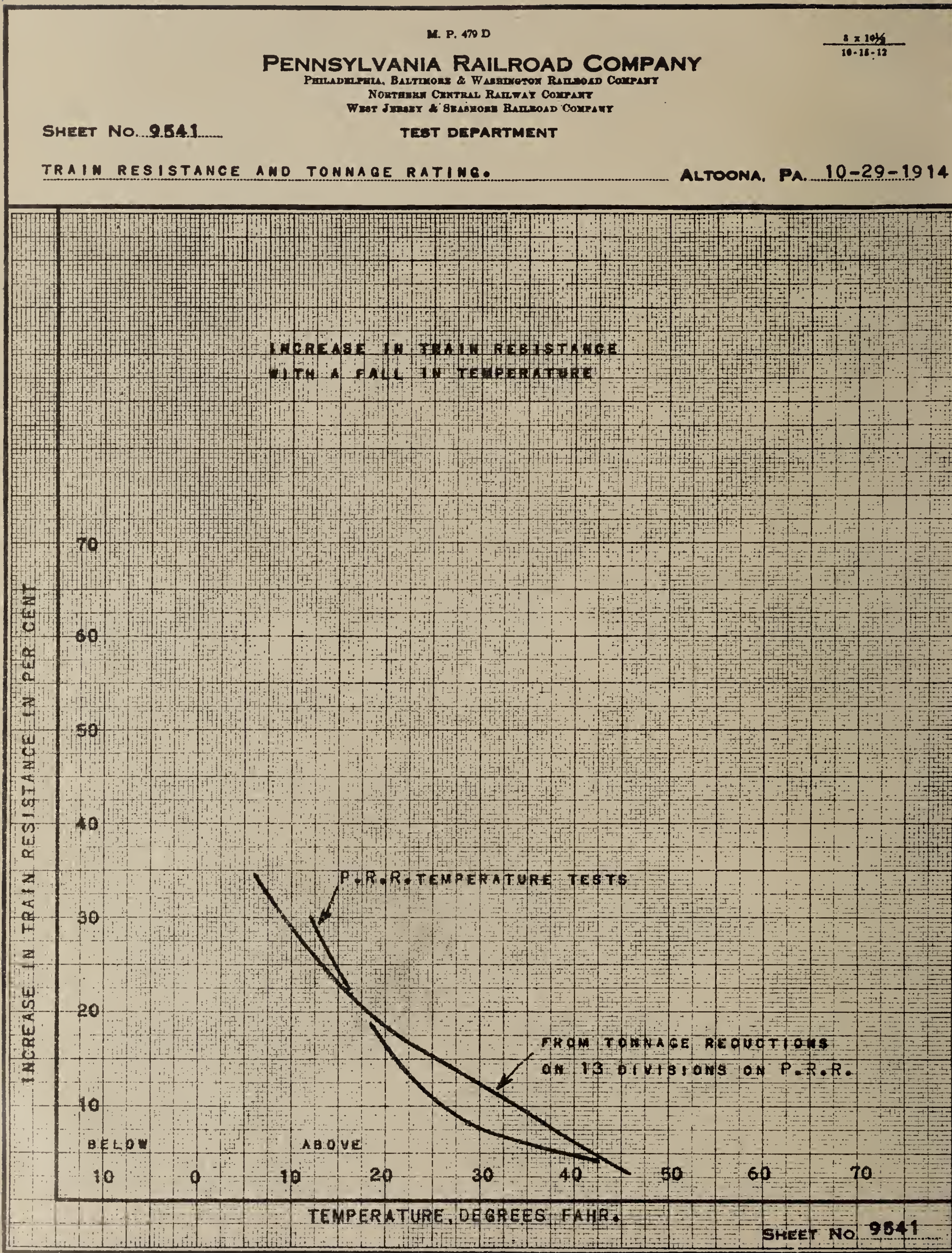

Fig. 17.

TEMPERATURE AND TRAIN RESISTANCE.

With a correct rating for summer temperature, a reduction may be necessary for temperatures below 45° F.

150. A detailed statement of the tonnage ratings that have been established, has been prepared by the General Manager in a form known as C.T. 200 which shows, for each division, the rating of each class of locomotive in use with the modifications of tonnage that are to be made on account of weather or other limiting conditions.

C. D. YOUNG,
Engineer of Tests.

APPROVED:
J. T. WALLIS,
General Superintendent Motive Power.

TEST DEPARTMENT,
ALTOONA, PENNA.,
October 15, 1915.

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